COOPERATIVE NATIONAL PARK RESOURCES STUDIES UNIT
UNIVERSITY OF HAWAI'I AT MĀNOA

Department of Botany
3190 Maile Way
Honolulu, Hawai'i 96822
(808) 956-8218

Clifford W. Smith, Unit Director

Technical Report 115

RARE PLANTS WITHIN MANAGED UNITS OF 'ŌLA'A FOREST, HAWAII VOLCANOES NATIONAL PARK

Linda W. Pratt and Lyman L. Abbott

United States Department of the Interior
USGS - Biological Resources Division
Pacific Island Ecosystems Research Center
Kilauea Field Station
P. O. Box 52
Hawaii National Park, HI 96718

University of Hawai'i at Manoa
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RARE PLANTS WITHIN MANAGED UNITS OF `ŌLA`A FOREST, HAWAII VOLCANOES NATIONAL PARK

Linda W. Pratt and Lyman L. Abbott

ABSTRACT

Four fenced pig-free management units and one adjacent unfenced area within the `Ōla`a Forest of Hawaii Volcanoes National Park were systematically searched for rare plants in 1992-94. Additional rare plant sightings were made off transects and on fencelines, while working on other projects in 1995-98. Observations by Resources Management workers were included on maps where possible. Only the western third of the `Ōla`a Forest was searched during this survey, where transects were placed systematically along north/south fence lines at intervals of 250-500 m. Those plants mapped on transects were within a 5-m belt. One listed endangered species, ha`iwale (*Cyrtandra giffardii*), was found in each surveyed unit, but was concentrated in the Ag and Koa Units below 1,280 m (4,200 ft) elevation. `Ōla`a has a larger population of this endangered species than anticipated, as 91 plants were counted along transects. A second endangered species, `ānunu (*Sicyos alba*), was encountered at four localities within the Koa Unit; this extremely rare vine is known from only two other Hawai`i Island sites.

Eight former candidate endangered plant species or "species of special concern" were counted along surveyed transects. Only six `akū (*Cyanea tritomantha*) were sighted in the Ag and Koa Units. The lobelioid, koli`i (*Trematolobelia grandifolia*), was more frequently seen, inside and outside the Pu`u Unit and in the lower Ag Unit. One hundred seventeen koli`i plants were counted along transects, and others were sighted off transect. Candidate endangered mints were very rare; only one *Phyllostegia floribunda*, nine *P. vestita*, fourteen mohihi (*Stenogyne scrophularioides*), and six *Stenogyne macrantha* were observed in the study area. The herb pōpolo kū mai (*Phytolacca sandwicensis*) was seen primarily in the Koa Unit, where 10 plants were counted. Only one individual of the vine *Schiedea diffusa* was found within `Ōla`a at the same Ag Unit site where it was discovered nine years ago; this is the only sighting of the species on Hawai`i Island in more than 80 years. Two endangered species (*Adenophorus periens, Clermontia peleana*), and three species of concern (*Asplenium schizophyllum, Eurya sandwicensis,* and *Joinvillea ascendens*) that were formerly reported from `Ōla`a Forest were not found in the study area in 1992-98.

Twenty additional plant species that are rare to uncommon in the Park were sighted within the `Ōla`a Forest study area. Two endemic orchid species (*Anoectochilus sandvicensis* and *Liparis hawaiensis*) were each found at only one `Ōla`a site. The rare vine kilioe (*Embelia pacifica*) occurred at five widely scattered sites in three units. Only 12 individuals of pāwale (*Rumex giganteus*) were observed; half of these were on transects, while others were on fence lines and at sites near transects. Eighty-three pala ferns (*Marattia*

douglasii) were counted along transects; these were concentrated in the Small Tract, Ag Unit, and outside the Pu`u Unit. These large terrestrial ferns are palatable to pigs and are sensitive to disturbance of the forest floor. The lobelioid `ōhā kēpau (*Clermontia hawaiiensis*) was noted at only one locality within the Ag Unit, but two other `ōhā species (*C. montis-loa* and *C. parviflora*) were relatively common in all five units of the study area. Two species of hāhā or *Cyanea* were less widely distributed within `Ōla`a Forest. *Cyanea degeneriana* plants were concentrated in or near the Pu`u Unit and inside the Ag Unit; 60 plants of this species were observed along transects, and a few others were growing on fence lines. Eighty-one *Cyanea pilosa* subsp. *longipedunculata* plants were found outside the Pu`u Unit and in the southern half of the Small Tract.

Ten of the 20 rare and uncommon plant species of `Ōla`a are shrubs or trees. Pāpala *(Charpentiera obovata*) and pāpala kēpau (*Pisonia brunoniana*), trees more common at mesic sites, were restricted to the Small Tract and the southwestern corner of the Koa Unit. `Aiea trees (*Nothocestrum longifolium*) and two species of shrubby kāmakahala (*Labordia hirtella* and *L. hedyosmifolia*) were widely scattered in all five units of `Ōla`a. Pilo kea (*Platydesma spathulata*) was very rare within the study area; only 18 pilo kea were noted on transects, and others were encountered off transect. Loulu palms (*Pritchardia beccariana*) were infrequently encountered, primarily in the Small Tract, Koa, and Ag Units. `Ohe mauka (*Tetraplasandra oahuensis*) trees, with one exception, were restricted to the Pu`u Unit, where 19 individuals were counted along transects and fence lines. Two members of the nettle family were also mapped along transects. Olonā (*Touchardia latifolia*) was most often seen within the Ag Unit, but was also scattered throughout the Koa Unit and Small Tract and was sighted once outside the Pu`u Unit. Ōpuhe (*Urera glabra*) was much rarer and was concentrated in the eastern half of the Small Tract and the adjacent area in the Koa Unit. Only 11 widely scattered individuals of maua (*Xylosma hawaiiense*), a tree also known from mesic forests, were sighted within the study area.

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INTRODUCTION

`Ōla`a Forest contains approximately a quarter of all the rain forest protected within Hawaii Volcanoes National Park and is the only Park rain forest on Mauna Loa substrates. Added to the Park as a non-contiguous parcel more than forty years ago (National Park Service 1985), the forest has been a focus of many recent research projects, particularly `ōhi`a (*Metrosideros polymorpha*) dieback studies carried out by University of Hawai`i ecologists and botanists (Mueller-Dombois 1977; Jacobi 1983a; Jacobi *et al.* 1983; Burton 1980). `Ōla`a Forest was recognized as an important habitat for rare plants during a preliminary biological survey 23 years ago (Jacobi and Warshauer 1975), and the area was sampled on two widely-spaced transects of the Hawaii Forest Bird Survey in the early 1980s. `Ōla`a was not systematically searched for rare and endangered plants until 1988 (Anderson *et al.* 1988a), when native vegetation and alien plant infestations throughout the forest were evaluated to facilitate the selection of management units to be fenced.

Hawaii Volcanoes National Park has within its boundaries (or formerly supported) populations of 25 listed or proposed threatened/endangered plant species and an additional 19 "species of special concern," most of which were previously candidate endangered species (U. S. Fish and Wildlife Service 1997). Four of the listed species and 11 of the former candidate endangered plant species are known to occur (or to have occurred) within `Ōla`a Forest. In addition to these, 20 of the 50 non-endangered plant species considered rare in Hawaii Volcanoes National Park (National Park Service 1996) are inhabitants of the `Ōla`a rain forest.

The current survey of rare plants in the western part of `Ōla`a Forest was undertaken as part of a research project designed to evaluate recovery from feral animal disturbance and to determine the distribution and abundance of rare plants, native birds, and selected invertebrate groups in the Park's most intact and intensively managed natural systems, called "Special Ecological Areas" or SEAs (Tunison *et al.* 1986; Tunison and Stone 1992). Results of bird and invertebrate surveys of `Ōla`a Forest will be presented in separate reports (Sarr *et al.* in prep., Foote *et al.* in prep.). The objectives of the rare plant survey of `Ōla`a were to document the presence and relative abundance of endangered and rare plants in the four fenced, pig-free units of `Ōla`a, as well as in one unprotected area for which fencing was proposed (and accomplished in 1997), and to evaluate the ecosystem management approach as a way to protect the Park's rare plants. Unlike the previous survey in 1988, the current search for rare plants was focused on areas actively managed at present, rather than on the entire forest. Additional goals for this survey were to provide information needed to develop management strategies for rare plants in `Ōla`a and to identify localities of rare plant populations for future research on population dynamics and limiting factors.

THE STUDY AREA

`Ōla`a Forest, a large parcel of rain forest in the Puna District, is not contiguous with the rest of Hawaii Volcanoes National Park. Portions of Volcano Village and cleared ranchland lie between `Ōla`a Forest and the Kīlauea District of the Park; Kīlauea Caldera is 3 km to the southwest. `Ōla`a is composed of two adjacent tracts of land separated by Wright Road (Fig. 1); these were both added to the jurisdiction of the Park in 1952 (National Park Service 1985). The Small Tract, on the west side of Wright Road, is approximately 144 ha (356 a) in area and is surrounded on three sides by pastures and residential lots. The Large Tract of `Ōla`a, east of Wright Road, is 3,765 ha (9,299 a) and measures 6 km from east to west. This large forest tract is bounded by farm lots, the Pu`u Maka`ala Natural Area Reserve (NAR), `Ōla`a Forest Reserve, and ranchland.

In response to concerns about damage to native plants and disturbance to Park rain forests (National Park Service 1973; Baker 1979), the Park Service began in 1980 to practice ecosystem management by incrementally fencing units within Hawaii Volcanoes and removing feral pigs (National Park Service 1996). In 1981, the Small Tract was the first of five units to be enclosed within `Ōla`a Forest. The Pu`u Unit was the next part of `Ōla`a Forest fenced against pigs in 1985. This 260 ha (650 a) unit is in the northwestern corner of the large tract and stretches from 1,280 m (4,200 ft) to 1,340 m (4,400 ft) elevation. The exclosure is approximately 1,200 m wide and 1,900 m long and is named for a prominent cinder cone (pu`u) in the southeastern corner of the unit. An equivalent unfenced area to the east, called the Pu`u Unit C, was also part of the current study. This area was unprotected during the course of the survey, although it was being considered for fencing (National Park Service 1996) and became part of a fenced management unit in 1997. Feral pigs have not yet been completely removed from this unit (now called the New Unit).

Directly to the south of the Pu`u Unit exclosure is the Ag Unit, completed in 1988 and named for the adjacent Agricultural Experiment Station on Wright Road. This small exclosure contains approximately 180 ha (450 a) and extends between the Pu`u Unit and the top of the more recently fenced Koa Unit near 1,220 m (4,000 ft) elevation. The Koa Unit is the largest of the five `Ōla`a exclosures with an area of 810 ha (2,000 a). This unit encloses the southwestern corner of the Large Tract between 1,070 and 1,220 m (3,500-4,000 ft) elevation, and is bounded by Wright Road and the Small Tract to the west and private pasture land to the south. The Koa unit is named for a kīpuka of koa (*Acacia koa*) forest to the east of the current study area; only the western half of the unit was surveyed for rare plants in 1992-94. The Koa Unit fence was completed in 1990, but the exclosure was not declared pig-free until 1994. This largest `Ōla`a exclosure likely had the highest pig density of all the management units; 126 feral pigs were removed between 1990 and 1994 (H. Hoshide, pers. comm. 1995). In the westernmost section of the Koa Unit, the lower half of the Pu`u Unit, and the entire Small Tract, Park managers have begun control of the most invasive alien plants; the area managed will be expanded in the future (C. Zimmer, pers. comm. 1998).

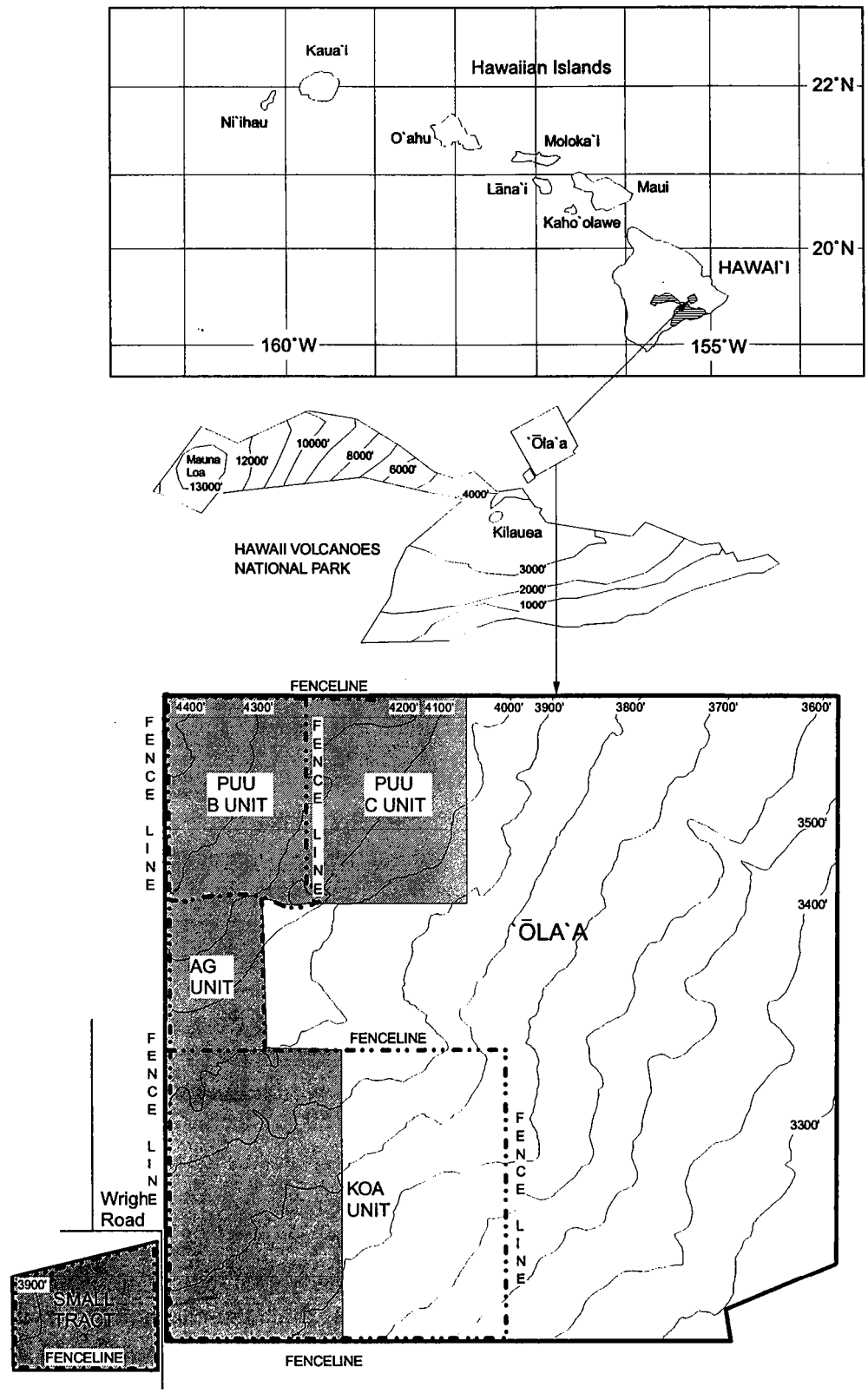

Figure 1. Four fenced management units and one unfenced unit (shaded) of the `Ōla`a Forest study area in Hawaii Volcanoes National Park.

Geology and Soils

The Park's large tract of `Ōla`a Forest is on the eastern slope of Mauna Loa Volcano near its contact with Kīlauea Volcano; the Small Tract lies directly on the interface of Mauna Loa with Kīlauea. Although no obvious line can be seen on the ground, roughly the northern half of the Small Tract is on Mauna Loa. In an early map of Mauna Loa substrates, the northern and eastern part of the study area were placed in the Kahuku volcanic series overlain by Pāhala ash. Portions of the Ag and Koa Units, as well as the Mauna Loa half of the Small Tract were mapped as the younger Ka`ū volcanic series (MacDonald *et al.* 1983). Most of `Ōla`a Forest stands on relatively old surfaces of Mauna Loa; only 10% of the volcano is covered by flows >4,000 years old (Lockwood and Lipman 1987). In a recent Mauna Loa mapping project, most of the `Ōla`a large tract substrates were dated at 7,000-7,999 years before present (bp)(Lockwood and Trusdell in prep.); substrates of this age underlie all of the Koa and Ag Units, and most of the Pu`u Unit. A portion of the Pu`u Unit was given a younger age of 4,000-4,999 years bp, and the uppermost part of the study area outside the exclosure includes substrates both younger and older (1,000-1,999 and 10,000-15,000 years bp). The northern half of the Small Tract was mapped as 4,000-4,999 years bp (Lockwood and Trusdell in prep.), while the southern half on Kīlauea Volcano was classified as part of the Volcano flows aged at 750 to 1,000 years; there is some possibility that these flows were actually of Mauna Loa origin (Holcomb 1987). Soils derived from volcanic ash cover the underlying substrates over most of `Ōla`a Forest; Pāhala ash deposits greater than 1.8 m in depth have been reported in this area (MacDonald *et al.* 1983).

Five different soil series were mapped within the study area by an early soil survey at a low intensity "reconnaissance" level with little ground truthing; these included Pi`ihonua silty clay loam, Lala`au extremely stony muck, Kahalu`u extremely rocky muck, `Akaka silty clay loam, and Puaulu silt loam (Sato *et al.* 1973). In a more recent, ongoing soil survey only the Puaulu silt loam series is still recognized in the study area, and other soils of the `Ōla`a Tract have been identified as complexes of three new soil series (K. Harrington, pers. comm. 1999). All the soils of the western part of `Ōla`a are derived from volcanic ash, but the newly recognized series differ in depth and type of underlying lava (`ā`a or pāhoehoe). In general, the soil type of the upper Pu`u Unit is 50-150 cm (20-60 in) deep over `ā`a, and the soils of the Ag and Koa Units are greater than 150 cm (60 in) deep over either `ā`a or pāhoehoe.

Climate

`Ōla`a Forest is in the montane wet zone with relatively cool temperatures and no pronounced dry season (Doty and Mueller-Dombois 1966). Mean annual rainfall in the `Ōla`a region is 3,000-4,000 mm (118-157 in), with wetter conditions to the east. At the nearby Wright Road farmlots, mean annual precipitation is 2,899 mm (114 in). Wettest months are in the winter and spring; summer months are drier, but monthly mean rainfall does not drop below 100 mm in any month (Giambelluca *et al.* 1986). Mean annual

temperature in the ʻŌlaʻa area falls between 15.6 and 18.3° C (60-65°F) (Hawaii Department of Land and Natural Resources 1970). Daily temperature highs and lows are higher during summer months but do not vary greatly throughout the year (Jacobi and Warshauer 1975). On the windward slopes of Mauna Loa, the ʻŌlaʻa region receives the prevailing northeast trade winds for much of the year. High winds are an occasional winter phenomenon; wind storms may result in heavy foliage loss and tree falls in ʻŌlaʻa (Gerrish 1980).

Vegetation

Four major rain forest types were recognized during the earliest survey of ʻŌlaʻa Forest: open ʻōhiʻa lehua (*Metrosideros polymorpha*) forest, closed ʻōhiʻa forest, hāpuʻu (*Cibotium* spp.) forest with scattered ʻōhiʻa, and koa (*Acacia koa*) forest (Jacobi and Warshauer 1975). All types except koa forest were found within the four fenced and one unfenced units of the current study area. In a later, systematic vegetation mapping project, most of the area now enclosed as the Puʻu Unit, all of the Small Tract, and portions of the Ag and Koa Units were mapped as open ʻōhiʻa forest with a secondary layer of native trees and an understory of hāpuʻu and native shrubs (Jacobi 1980a, 1980b, 1983b). Patches of closed ʻōhiʻa forest were recognized inside and outside the Puʻu Unit and were the predominant type of the Ag Unit. The eastern part of the study area in the Koa Unit was mapped as wet forest of scattered ʻōhiʻa with an understory of hāpuʻu and native shrubs. The formerly unfenced area outside the Puʻu unit exclosure was also mapped as open ʻōhiʻa forest, and below about 1,270 m (4,160 ft) elevation snags were a component of the vegetation type. Forests of scattered ʻōhiʻa trees and areas where snags are prominent are symptomatic of ʻōhiʻa dieback, a natural successional phenomenon well studied in ʻŌlaʻa Forest (Jacobi *et al.* 1983; Mueller-Dombois *et al.* 1980). ʻŌlaʻa Forest provides the best example on the island of "displacement dieback," where tree ferns become dominant after large ʻōhiʻa trees die (Mueller-Dombois *et al.* 1977).

METHODS

Transects used to map rare plants inside the Puʻu Unit exclosure were relocated from an earlier study of vegetation established immediately after fence construction (Anderson and Higashino 1985-87). In the earlier study, the location of the first transect below the upper northern fence line was determined using a random point in the first km along the western exclosure fence line (495 m). Subsequent transects were placed at 400 m intervals along the western fence line and stretched across the exclosure to the eastern fence line. Transects outside the Puʻu Unit exclosure (Unit C) were continuous with those inside the exclosure, except for Transect 2C, which was re-established starting on the inner Unit fence line, 500 m south of the upper boundary fence. Except for Transect 2C, the transects outside the Puʻu Unit were also originally used by the previous study (the first 200 m), and in 1992 transects were extended to 1200 m to match the area covered within the Puʻu exclosure. All ten transects used to search for rare plants in the Ag and Koa Units were originally placed

by Resources Management personnel to monitor pig activity and alien plants. Monitoring transects of the Ag Unit were 400 m apart, starting 400 m from the Pu`u/Ag Unit fence line, and they extended approximately 800 m from the western to the eastern exclosure fence line. Management monitoring in the large Koa Unit was more intensive with transects placed at 250 m intervals. For the rare plant survey, the first 1,600 m of every other Koa Unit transect was searched, so intervals between transects were approximately 500 m. Transects within the Small Tract were put in place specifically for the Special Ecological Areas project. The first transect began on the Wright Road fence line at a random number within the first 250 m of the corner of the unit; subsequent transects were placed at 200 m intervals along the fence line parallel to Wright Road. Transects extended from Wright Road approximately 1,200 m to the western fence line of the Small Tract that separates the Park from private pastureland.

A list of rare plants in `Ōla`a Forest was developed before field work began; all endangered and candidate endangered plants known or suspected from `Ōla`a were included on the list of search targets, along with approximately 20 other rain forest species on the Park`s rare plant list (National Park Service 1996). Rare plants were counted along transects in a belt 5 m wide; locations were recorded using distances measured and flagged in 10 m increments along transects. For this report, numbers of each rare plant species were mapped in 100 m increments along transects. For some plant species rarely encountered on transects, off-transect locations along fence lines, cross-trails, or plots established for other studies were also mapped. For all species except lobelioids, rare plant surveys were carried out by the same botanist, with assistance from one or two other botanists. Lobelioid numbers were obtained by three botanists focusing specifically on *Clermontia* spp. and *Cyanea* spp.; information on size classes and rooting sites of these species was presented in a separate report (Pratt and Abbott in prep.). All transects (except those of the Ag Unit) were examined twice for rare plants and lobelioids in 1992-94, and additional sightings were made during trips to the study area for work on other research projects in 1995-98. The Ag Unit was searched for rare plants only once in 1994. Rare plant sightings reported by Resources Management personnel in or near the study area were also mapped, where possible. Appendix 1 lists label information from specimens of rare plants collected in and near `Ōla`a Forest and deposited in the Hawaii Volcanoes National Park Herbarium.

RESULTS AND DISCUSSION

Listed Endangered Plant Species

Two listed endangered plant species were found in the surveyed sections of `Ōla`a Forest either during the 1992-94 survey or during subsequent research work: ha`iwale (*Cyrtandra giffardii*) and `ānunu (*Sicyos alba*). `Ānunu was not found along the surveyed transects, but was sighted between transects during other projects in 1996-1998. Two

additional endangered species have been previously observed within ʻŌlaʻa, but were not seen during the current survey: kihi (*Adenophorus periens*) and ʻōhā (*Clermontia peleana*).

Haʻiwale (*Cyrtandra giffardii*) - There is no specific common name for this species, but other members of this genus in the African violet family (Gesneriaceae) are called haʻiwale. Haʻiwale are brittle-stemmed shrubs or small trees that have opposite or whorled leaves, white tubular flowers, and white berries. *Cyrtandra giffardii* is a large shrub or small tree with sparsely hairy, opposite leaves. Its white flowers are distinguished by their narrow calyx lobes, and its small, white berries are more rounded than is usual in other Hawaiian *Cyrtandra* (Wagner *et al.* 1990). The species is endemic to Hawaiʻi Island, where it is distributed on the windward slopes of Mauna Kea and Mauna Loa at sites such as Laupāhoehoe NAR (Cuddihy *et al.* 1982), the Kulani/Stainback Highway area, and Puʻu Makaʻala NAR (U. S. Fish and Wildlife Service 1994a; Wagner *et al.* 1990). Kīlauea is the type locality for the species, which was first collected in forests near the Volcano House in 1911 (Rock 1919a). Fosberg (1966) listed the species from "Kīlauea" in his Park checklist, but because no recent specimens had been collected, Wagner *et al.* (1990) concluded that the Kīlauea population was possibly extinct.

During the 1992-94 survey of ʻŌlaʻa Forest, 91 *Cyrtandra giffardii* were seen along transects in the five units. Only fertile plants that could be definitely assigned to the rare species were counted along transects; other sterile *Cyrtandra* plants that may have been *C. giffardii* were not recorded. Plants were found in the surveyed exclosures and one unfenced area between 1,130 and 1,340 m (3,700-4,400 ft) elevation in closed montane wet forest of ʻōhiʻa lehua and hāpuʻu. *Cyrtandra giffardii* plants were concentrated in the Koa Unit (55 plants) and the Ag Unit (27 plants), but a few individuals were found within the Puʻu Unit exclosure, outside the Puʻu Unit exclosure (Unit C), and in the northeast corner of the Small Tract (Fig. 2). Additional *Cyrtandra giffardii* plants (32) were found in 1994 within the Koa Unit at three sites between transects. Many more individuals certainly occur in unsurveyed areas between transects and to the east.

No stand structure analysis of the species was carried out, but both large and small individuals were noted. Very small plants and juveniles were difficult to distinguish from other *Cyrtandra* species more common in ʻŌlaʻa (particularly *C. lysiosepala*). Although phenological data were not collected during this survey, flowers and/or fruits were observed on most large *Cyrtandra giffardii* in both summer (July) and winter (January-February). Other observers have noted flowers on this species in June, November, December, and January (U. S. Fish and Wildlife Service 1996a). Reasons for the rarity of this species are not known, but feral pigs and habitat destruction are suspected causes of decline (U. S. Fish and Wildlife Service 1994a).

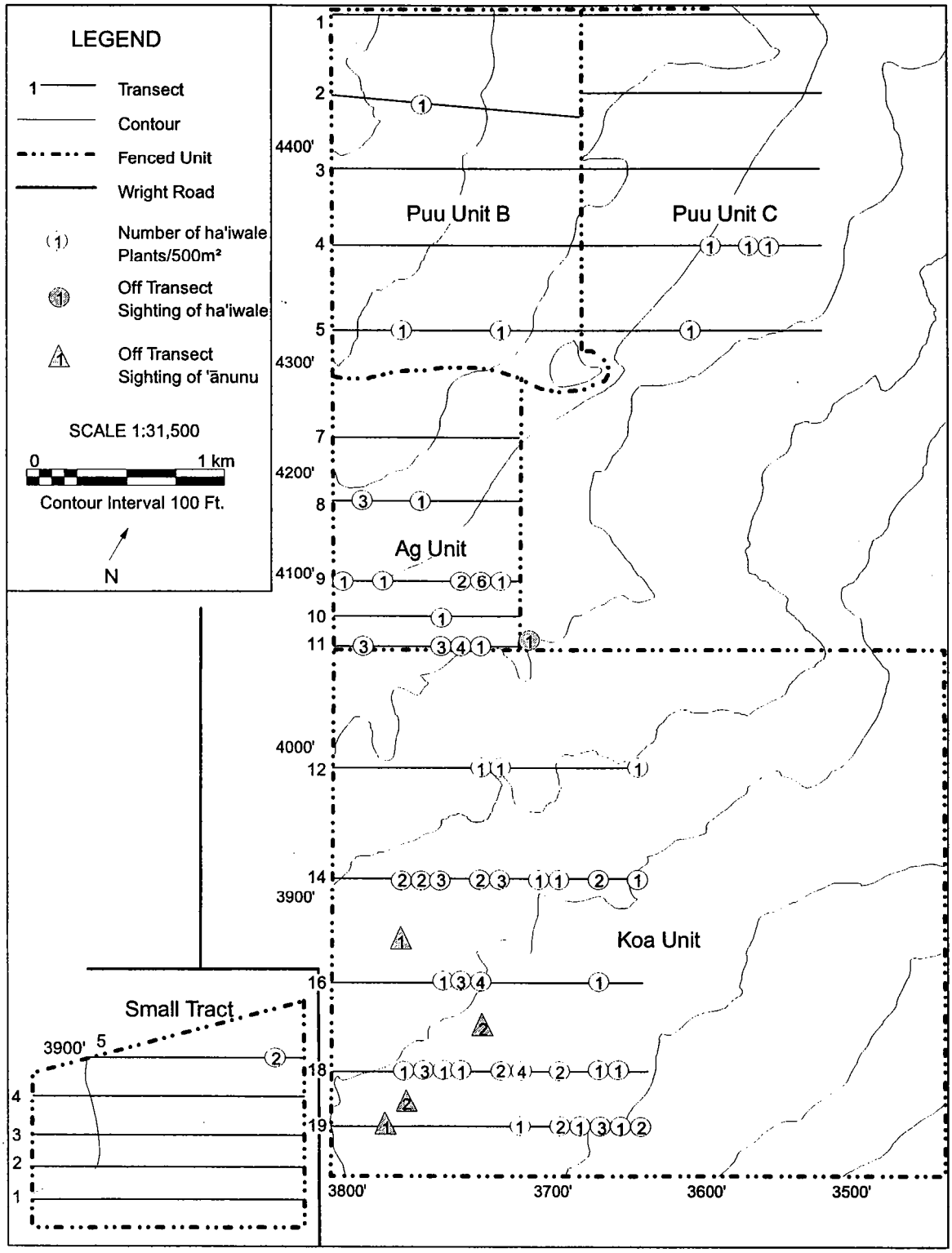

Figure 2. Distribution of ha'iwale (*Cyrtandra giffardii*) and 'ānunu (*Sicyos alba*) along transects in five units of 'Ōla'a Forest, Hawaii Volcanoes National Park.

There is no available information on changes in distribution or abundance of *Cyrtandra giffardii* within ʻŌlaʻa Forest. Jacobi and Warshauer (1975) did not identify *C. giffardii* among the *Cyrtandra* they collected in ʻŌlaʻa 23 years ago, although one of the four unidentified species they encountered may be this endangered plant. Anderson *et al.* (1988a) did not collect data on *Cyrtandra giffardii*. Based on the findings of the current survey, *Cyrtandra giffardii* appears to be flourishing within the protected, pig-free exclosures in the eastern part of ʻŌlaʻa Forest. Future monitoring of this species is warranted to determine its reproductive status.

ʻĀnunu (*Sicyos alba*) - ʻĀnunu , an annual vine in the gourd family (Cucurbitaceae), was proposed as an endangered species in 1995 (U. S. Fish and Wildlife Service 1995) and was subsequently listed as endangered (U. S. Fish and Wildlife Service 1996b). The species was formerly known as *Sarx alba* (St. John 1978). This herbaceous vine is endemic to Hawaiʻi Island, where it has been collected on Mauna Kea, in Puʻu Makaʻala NAR, and at Kīlauea. Apart from the plants found during the current survey, only two extant populations with 21 individuals are known (U. S. Fish and Wildlife Service 1996b). One of the known ʻānunu sites is ʻŌlaʻa Forest Reserve, adjacent to the Park's ʻŌlaʻa Forest.

No ʻānunu plants were found along transects during the rare plant survey, but six vines have been sighted off-transect in the Koa Unit since 1996. In 1989, a sterile *Sicyos* was collected in the Koa Unit by Tim Tunison of the Park's Resources Management Division. The general area of the 1989 *Sicyos* collection was searched unsuccessfully several times in 1992-94. In 1996, during work on another research project, two large ʻānunu vines were found between two surveyed transects in the Koa Unit, approximately 750 m east of Wright Road and 400 m from the 1989 collection site (Fig. 2). Both flowers and fruits were present in June 1996, permitting identification of the vine. *Sicyos alba* has persisted at this site for more than two years and in the general area for nine years. Four other *Sicyos alba* were subsequently sighted by Resources Management and BRD personnel at three localities in the Koa Unit; one site is between transects 14 and 16 to the north of previous sightings, and the second is between transects 18 and 19, where alien plant control workers found at least two fertile *Sicyos alba* 400-500 m from the road. The third new site is near a research plot close to transect 19.

Twenty-three years ago, Jacobi and Warshauer (1975) also collected a *Sicyos* in ʻŌlaʻa Forest within the area now enclosed as either the Koa or Ag Unit. If, as seems likely, this unidentified *Sicyos* was also *S. alba,* the species has persisted with very low numbers in the same general area within ʻŌlaa Forest for more than two decades. The Koa Unit is today the only site on the island at which *Sicyos alba* is protected from feral pigs by fencing, although an area of nearly 300 acres in Puʻu Makaʻala NAR has been recently proposed by NARS staff and the Regional Forest Management Advisory Committee as a fenced exclosure to protect the species (Stormont 1998).

Endangered Plant Species Not Found in `Ōla`a Forest in 1992-94 - One endangered fern and one endangered lobelioid were not found in the current survey, although they have been sighted in or near `Ōla`a Forest in the recent past. Pendent kihi (*Adenophorus periens*), a small epiphytic fern in the grammitis family (Grammitidaceae), was formerly distributed on six of the main Hawaiian Islands (Bishop 1974), but in the last 50 years the rare fern has been collected at only a few sites on three islands (U.S. Fish and Wildlife Service 1994b). The largest known population of this plant is at Kahauale`a (Char and Lamoureux 1985), on Kīlauea's East Rift adjacent to the Park. The species also formerly occurred within Hawaii Volcanoes on Kāne Nui o Hamo (Cuddihy *et al.*1986), but has apparently disappeared from the Park's East Rift forests since the beginning of the current Pu`u `Ō`ō eruption (Pratt *et al.* 1998). One kihi plant was found within `Ōla`a Forest in the late 1980s near the edge of the area now enclosed by the Koa Unit (Paul Higashino, pers. comm. 1996), but plants of this population were not relocated during the current survey. Pendent kihi is most often an epiphyte on large-diameter `ōhi`a lehua trees, but may also occur on other native trees. The small fern appears to require the dense shade of undisturbed rain forest as habitat.

The endangered `ōhā or *Clermontia peleana* subsp. *peleana*, a Hawai`i Island endemic, is a small tree with dark purple, curved flowers. Extremely rare, this species has been collected on the slopes of Mauna Kea, particularly along the Wailuku River and nearby streams, and on Mauna Loa in the vicinity of Glenwood (Lammers 1991). The type locality of the species is "near Glenwood along the road to the Volcano", where Joseph Rock first collected the plant in 1911 (Rock 1919b). Degener subsequently collected this `ōhā "at an elevation of 3,800 ft, four or five miles below Kīlauea Volcano, along the government road" (Degener and Degener 1960). One Park checklist listed a collection of *Clermontia peleana* from "Kīlauea in tall *Metrosideros* forest" (Fosberg 1966); this specimen was collected in `Ōla`a Forest, possibly within the are now enclosed by the Koa Unit (D. Mueller-Dombois, pers. comm. 1995). The species has not been seen within the Park in 30 years.

Species of Concern and Former Candidate Endangered Plant Species

Eight "species of special concern" were found within the study area of `Ōla`a Forest during the 1992-94 survey. Two of these had been on the list of candidate endangered species for a number of years (U. S. Fish and Wildlife Service 1980), most recently as Category 2 candidates, about which little is known; these are the lobelioids `akū (*Cyanea tritomantha*) and koli`i (*Trematolobelia grandifolia*). Six other `Ōla`a species were recently added to the list of "species of special concern" maintained by the U. S. Fish and Wildlife Service (U. S. Fish and Wildlife Service 1997), including four endemic mints (*Phyllostegia floribunda, P. vestita, Stenogyne macrantha* and *S. scrophularioides*), pōpolo kū mai (*Phytolacca sandwicensis*), and the vine *Schiedea diffusa*. Three species of concern that were formerly collected or sighted in `Ōla`a Forest were not found during the current survey.

`Akū *(Cyanea tritomantha)* - `Akū, a single-stemmed, palmlike shrub in the lobelia subfamily of the bellflower family, has a succulent, prickly stem; large, prickly leaves; and curved, white flowers clustered beneath the leaves at stem tips. Endemic to the island of Hawai`i, `akū was formerly known from the windward slopes of Mauna Kea, Mauna Loa, Kohala Mountains, and Kīlauea (Rock 1919b). Today `akū is known from fewer than 10 populations with 100-500 individuals total (U. S. Fish and Wildlife Service 1997). One of the most vigorous populations of `akū occurs within Pu`u Maka`ala NAR adjacent to the Park's `Ōla`a Forest. Within Hawaii Volcanoes National Park, `akū seems to be restricted to `Ōla`a Forest, although the species may formerly have occurred in other Park rain forests. Based on observations of the species in Puna Forest Reserve east of the Park (Char and Lamoureux 1985) and early collections near Hilo and in lowland forests of Ka`ū (Rock 1919b), low-elevation rain forests are potential habitat for `akū. Like most other endemic members of the lobelioid group, `akū is extremely vulnerable to damage from feral pigs that have impacted most of its Hawai`i Island rain forest habitat.

Only six `akū plants were found on or near transects within the fenced exclosures of `Ōla`a in 1992-94 (Fig. 3); these few plants were widely scattered in the western part of the Koa and Ag Units. Other `akū individuals have been previously reported by Resources Management personnel (L. Katahira, T. Tunison, pers. comm., 1994), primarily in the Koa Unit and Small Tract. There is little information on the population structure of `akū in `Ōla`a, but both young plants <0.5 in height and mature individuals >1.5 m tall have been observed. One individual seen first in 1990 (L. Katahira, pers. comm. 1996) grew in height from 15 cm to >50 cm in three years. This individual persisted into 1998, when its height was measured as 110 cm. This lobelioid is extremely rare in the surveyed part of the Park's `Ōla`a Forest, far rarer than in the adjacent Pu`u Maka`ala NAR. `Akū plants in the Natural Area Reserve are found on a younger, rockier substrate than occurs in `Ōla`a Forest; the more shallow soil and abundance of surface rocks may discourage feral pig rooting in Pu`u Maka`ala. Rats are also a threat to this species; rat-gnawed `akū stems have been observed during dry periods.

Jacobi and Warshauer (1975) found `akū to be uncommon in closed `ōhi`a/hāpu`u forest during their survey 23 years ago; they sighted the species in the eastern part of what is now the Koa and Ag Units. Anderson *et al.* (1988a) observed only two `akū plants, on two of eight transects that traversed the entire large tract of `Ōla`a; only one `akū plant was seen within the forest now enclosed as the Koa Unit. `Āku may have been lost from the Small Tract; none was found during this survey, while at least six plants were observed in 1985 (T. Tunison, pers. comm 1998). This species has apparently never been common in the Kīlauea area in historical times, and remains one of the rarest native plants of Hawaii Volcanoes National Park.

Koli`i *(Trematolobelia grandifolia)* - *Trematolobelia* is another endemic genus in the lobelia subfamily. The Park's *Trematolobelia* or koli`i was formerly known as

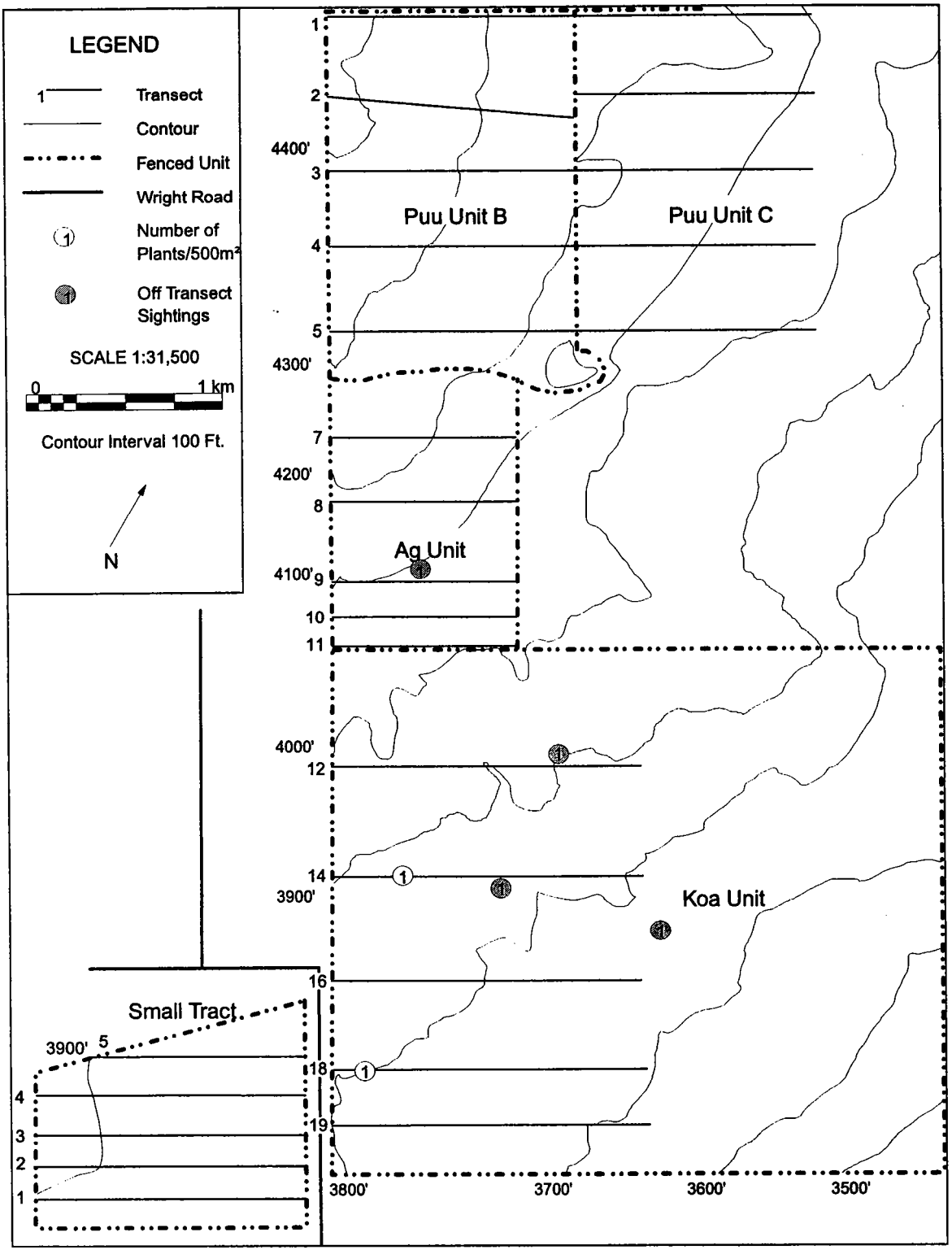

Figure 3. Distribution of 'akū (*Cyanea tritomantha*) along transects in five units of 'Ōla'a Forest, Hawaii Volcanoes National Park.

a variety of the more widespread *T. macrostachya* (Rock 1919b), found on five Hawaiian Islands (Wagner *et al.* 1990). The koli`i of Kīlauea and Mauna Loa are today considered members of the species *T. grandifolia*, but they have also been known by the name *T. wimmeri* (St.John 1982). In the current treatment of the genus, *T. grandifolia* is considered to be an island endemic, restricted to the Kohala Mountains, the Mauna Kea saddle, Mauna Loa, and Kīlauea (Wagner *et al.* 1990). Koli`i has also been observed north of Hilo and on the slopes of Hualālai in Kona. The `Ōla`a koli`i is a monocarpic shrub, often unbranched, with narrow smooth leaves, and large inflorescences of curved white flowers. Like other koli`i, its fruits are dry capsules that release their seeds by irregular pores in the inner fruit wall that appear as the outer capsule walls decompose. St John (1982) estimated that koli`i shrubs were mature after eight or more years and died after producing flowers and fruits. As with other members of this large family, stems of koli`i are fleshy, brittle, and easily broken by feral animals.

During the 1992-94 systematic survey of the five `Ōla`a units, 117 koli`i plants were found along transects, and a few additional plants were seen along fence lines near transects (Fig.4). Eleven koli`i occurred along transects in the Pu`u Unit exclosure. Seven additional plants were found along the interior fence line; and four others were noted along the upper fence line just outside the exclosure. Outside the Pu`u Unit exclosure in Unit C (in what is now the New Unit), 40 koli`i were seen on transects and three were noted along the exclosure fence line. In the Ag Unit, 58 koli`i plants were clustered at one site along the lower fence line. The Koa Unit had only eight koli`i along transects. No koli`i were found in the Small Tract in 1992, but two young plants were observed in 1994. While the species was widespread within the study area, koli`i plants were concentrated in relatively few sites. Koli`i was most abundant at one locality on Transect 3C outside the Pu`u Unit (Fig. 4), where plants were tagged and measured for future monitoring (including both on- and off-transect plants). In 1994, there were 82 individuals in an area approximately 220 $m^2$. The mean height of koli`i plants at this site was 28.6 cm; most plants (76.8%) were in the 10-50 cm height class (Table 1). Few koli`i plants were terrestrial (6.1%); most were epiphytic on tree fern trunks (79.3%) or `ōhi`a logs (14.6%). The mean height above ground of epiphytic koli`i plants was 27.4 cm. When this site was revisited in 1998, none of the individuals tagged in 1994 remained alive, but 31 new plants were growing at the site.

Little change was noted in the number of koli`i observed in 1992 versus 1994 in the Koa Unit, but large increases were observed both inside and outside the Pu`u Unit. On those transects that were re-monitored in 1994 (2-5), the number of koli`i plants doubled in the area outside the Pu`u Unit, and a fifteen-fold increase occurred within the enclosed Pu`u Unit. Most plants counted in 1994 were in the <10 and 10-50 cm height classes, and were likely progeny of large plants noted in 1992.

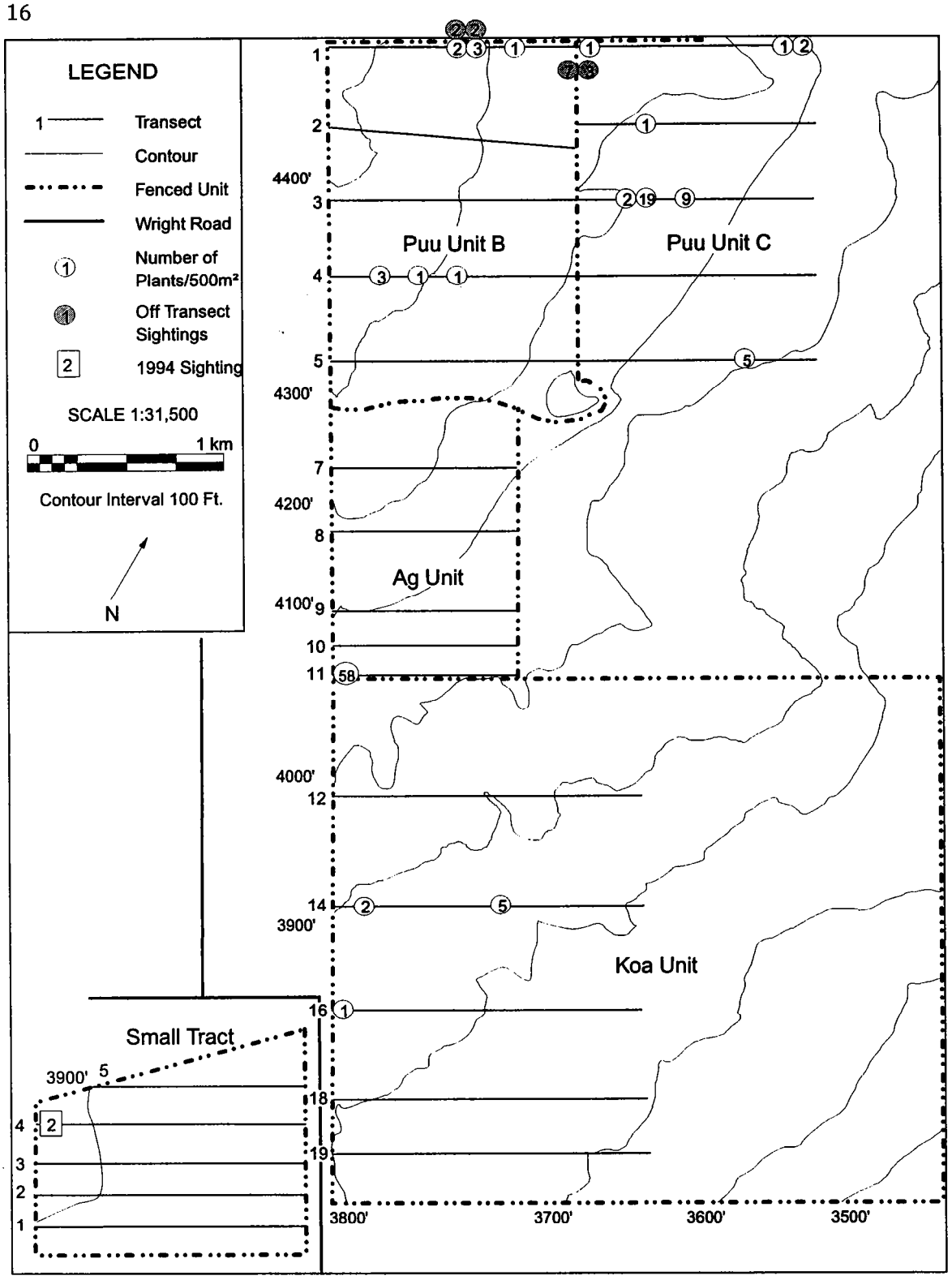

Figure 4. Distribution of koli'i (*Trematolobelia grandifolia*) along transects in five units of ʻŌlaʻa Forest, Hawaii Volcanoes National Park.

Table 1. Height and rooting category of koli`i (*Trematolobelia grandifolia*) at one site outside the Pu`u Unit exclosure, `Ōla`a Forest.

Height Class (cm)	Rooting Category	Number of Plants	% of Total
< 10	Terrestrial	1	1.2
< 10	Epiphytic	9	11.0
< 10	All	10	12.2
10-50	Terrestrial	4	4.9
10-50	Epiphytic	59	72.0
10-50	All	63	76.8
> 50-100	Terrestrial	0	0
> 50-100	Epiphytic	8	10.0
> 50-100	All	8	10.0
>100-200	Terrestrial	0	0
>100-200	Epiphytic	1	1.2
>100-200	All	1	1.2

Relatively few koli`i plants were found in the surveyed part of the Koa Unit (Fig. 4), indicating that the area is not preferred habitat for the species, but the unsurveyed eastern half of the exclosure is known to support many koli`i (Anderson *et al.* 1988a). The species was abundant within koa/`ōhi`a lehua forest of the kīpuka that is now bisected by the eastern fence line of the exclosure. Twenty-three years ago, koli`i was rated as uncommon in closed to open `ōhi`a lehua forest of the area now enclosed by the Pu`u, Ag, and Koa Units, but was occasionally encountered within the koa kīpuka forest (Jacobi and Warshauer 1975); the species was found only rarely in the Small Tract. Jacobi and Warshauer commented that koli`i was invariably seen as an epiphyte in `Ōla`a. Other regions of the Park known to harbor koli`i are forests of the eastern rim of Kīlauea Iki, where the species was collected in the 1940s (Fagerlund and Mitchell 1944) and has persisted to the present, and Kāne Nui o Hamo on Kīlauea's East Rift (Pratt *et al.* 1998). At Kāne Nui o Hamo, koli`i grows on the upper slopes of the forested shield and within the nearly inaccessible crater (Belfield 1998). Koli`i has persisted at several sites within the Park for decades despite disturbance of its rain forest habitat by feral pigs. Because of its wide distribution and relatively large known population size, koli`i appears to be secure within Hawaii Volcanoes National Park, especially in pig-free exclosures. Further monitoring will reveal more about the species' population structure and longevity.

Native Mints - Four endemic members of the mint family (Lamiaceae) found in `Ōla`a Forest are rare and deserve consideration as threatened or endangered species. *Phyllostegia floribunda* and *P. vestita* are both Hawai`i Island endemics with no recorded common names. *Stenogyne macrantha* and *S. scrophularioides* or mōhihi are members of a genus endemic to the Hawaiian Islands. Like the *Phyllostegia* of `Ōla`a, they are also restricted to Hawai`i Island. One other uncommon mint (*Phyllostegia ambigua)* was found once along a fence line in `Ōla`a Small Tract in the recent past (1985); this species is not considered to be rare on the island.

Phyllostegia floribunda is a shrub with variably hairy leaves and small axillary inflorescences of red tubular flowers; plants from the Kīlauea region were formerly known as *P. villosa* (St. John 1976). The current distribution of *Phyllostegia floribunda* is thought to be four disjunct areas on windward Hawai`i, including the Kohala Mountains, Parker Ranch, Ka`ū, and wet forests from Kīlauea to Laupāhoehoe on Mauna Kea (Wagner *et al.* 1990). In Laupāhoehoe NAR, this mint has been found in koa/`ōhi`a forest at elevations of 1,040-1,160 m (3,400-3,800 ft) (Cuddihy *et al.* 1982). The species also formerly occurred near Hilo and in the districts of Puna and Kona (Sherff 1935); some Kona specimens were previously known as a distinct species (*P. forbesii*) (St. John 1976).

Only one individual *Phyllostegia floribunda* was found during the 1992-94 survey of `Ōla`a Forest, on the inner, eastern fence line of the Ag Unit just south of the Pu`u Unit exclosure (Fig. 5). Flowers were observed on this plant in the summer (July), but young plants or progeny were never observed. The site supporting this rare species did not differ noticeably from the surrounding forest. The reasons for *P.* floribunda's extreme rarity in `Ōla`a are not known, but long-term disturbance by feral pigs may be a factor. This species was not observed during previous surveys of `Ōla`a Forest (Jacobi and Warshauer 1975, Anderson *et al.* 1988a) and did not occur in `ōhi`a dieback study plots in `Ōla`a, although it was noted in Waiākea Forest Reserve plots northeast of `Ōla`a (Mueller-Dombois *et al.* 1980). *Phyllostegia floribunda* is currently known from only one other site in Hawaii Volcanoes National Park, a pig-free crater near Nāpau Crater on Kīlauea's East Rift (Belfield 1998). The species was listed on earlier Park checklists from "Kīlauea" (Fosberg 1966) because of collections made in 1910 (Sherff 1935) and 1926 (St. John 1976).

Phyllostegia vestita is a vine with densely pubescent leaves and congested terminal inflorescences of white to pink flowers. Although widely distributed on the windward slopes of Hawai`i Island (Wagner *et al.* 1990), this species is uncommon throughout its range and may have disappeared from some past collection sites (Sherff 1935) that have been greatly altered. Habitat loss, feral pigs, and alien invertebrates (slugs and insects) may contribute to the decline of this species. Only eight *Phyllostegia vestita* were observed in `Ōla`a Forest during the 1992-94 survey, and one plant was found during a subsequent research project in 1996. Most of these plants were growing in Unit C outside the Pu`u Unit exclosure; only

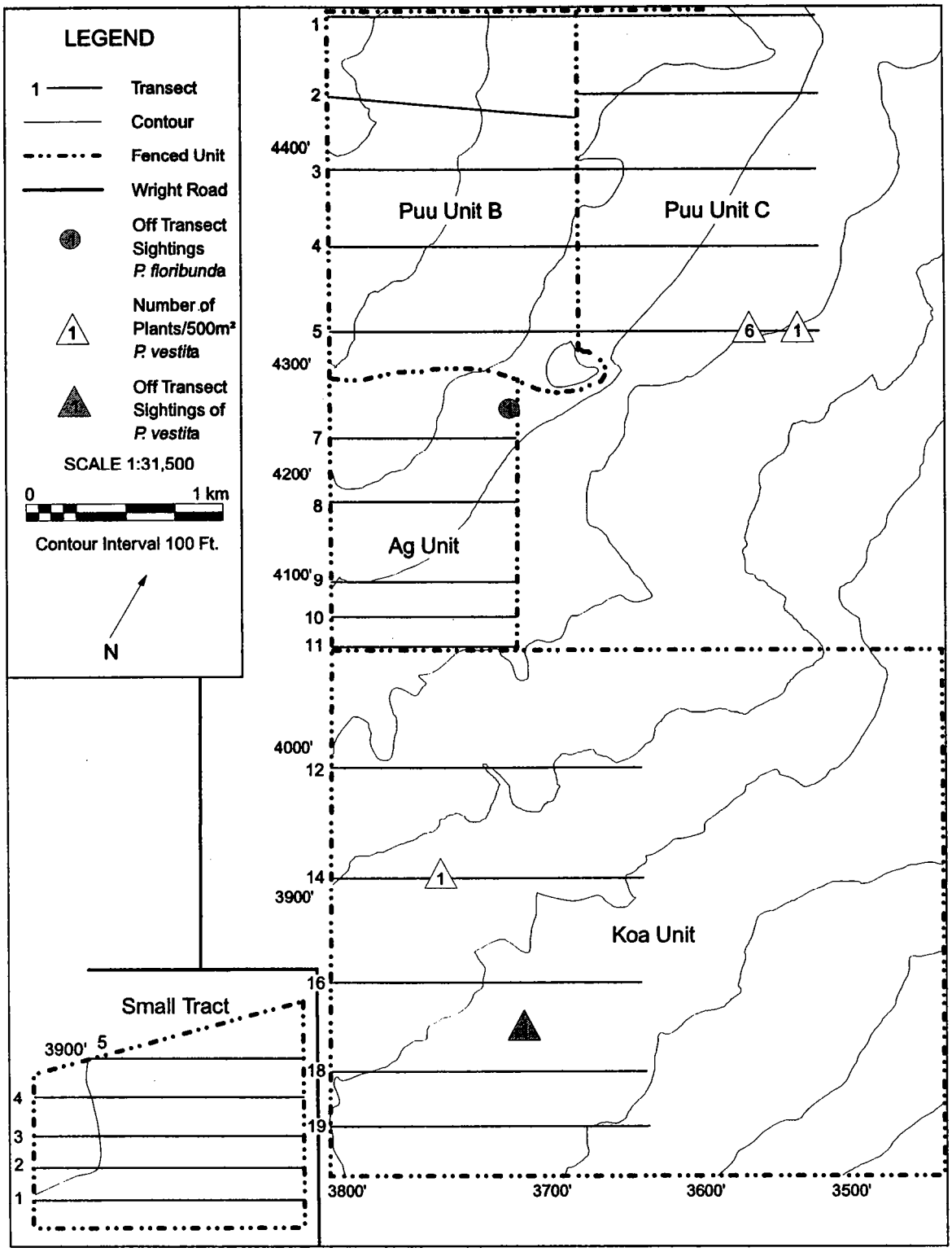

Figure 5. Distribution of *Phyllostegia floribunda* and *P. vestita* along transects in five units of 'Ōla'a Forest, Hawaii Volcanoes National Park.

two vines were found within the protected Koa Unit (Fig. 5). Flowers and fruits were observed during the spring and summer (March, May, and August). Most plants showed heavy insect damage to foliage. *Phyllostegia vestita* was not found by Jacobi and Warshauer (1975) or Anderson *et al.* (1988a) during their surveys of `Ōla`a Forest, although the latter survey noted one unidentified *Phyllostegia* more than a km east of the Pu`u Unit. In the last 20 years, this mint has been sighted during surveys and studies of the adjacent Pu`u Maka`ala NAR (Mueller-Dombois *et al.* 1980; The Nature Conservancy 1989). The species was listed on earlier Park checklists (Fosberg 1966; Fagerlund and Mitchell 1944) as present in forests near Nāpau Crater (Fagerlund and Mitchell #567, HAVO Herbarium). Although the species was feared extirpated from East Rift forests by lava flows and feral pigs, *Phyllostegia vestita* has been recently rediscovered in the pit crater of Kāne Nui o Hamo (Belfield 1998).

Stenogyne macrantha is a vine with densely hairy, heart-shaped leaves and yellow to pale pink tubular flowers. Distributed in wet forests at middle elevations on Hawai`i Islands (Wagner *et al.* 1990), this *Stenogyne* was formerly considered a candidate endangered species (U. S. Fish and Wildlife Service 1980), and is now a "species of special concern". The species is restricted to wet forest habitat and is largely terrestrial; past disturbance by feral pigs may contribute to the rarity of this species. Only three *Stenogyne macrantha* vines were found along transects in the surveyed part of `Ōla`a Forest, at one site within the Ag Unit (Fig. 6). In addition, one *Stenogyne macrantha* was seen in the Koa Unit east of the study area, and one vine was noted along the access trail through Pu`u Maka`ala NAR. This latter plant has been in the same place for at least a decade, but has never been observed with flowers. Elsewhere, flowers were observed on several *Stenogyne* vines in May, but young plants were not seen in `Ōla`a Forest. Jacobi and Warshauer (1975) did not list this species from `Ōla`a, but they did find two unidentified *Stenogyne* species that were rare in the western part of `Ōla`a. Anderson *et al.* (1988a) did not observe *Stenogyne macrantha* within `Ōla`a during their survey. The species was noted as rare more than a decade ago in the nearby Kīlauea Forest, Keauhou Ranch, and Upper `Ōla`a Forest Reserve above 1,310 (4,300 ft) elevation (Clarke *et al.* 1982). Apart from `Ōla`a Forest, this species is not known to occur elsewhere within the Park.

Mōhihi or *Stenogyne scrophularioides* is a vine with small, ovate, toothed leaves and pale yellow to green tubular flowers. The species is distributed in low- to mid-elevation wet forests of Hawai`i Island, primarily on Mauna Loa (Wagner *et al.* 1990). Several varieties of the species were formerly recognized (Sherff 1935); all varieties and five other named species were recently consolidated into *S. scrophularioides* (Wagner *et al.* 1990). Most early collections of the species were made in the vicinity of Hilo (Sherff 1935). As the lower forests of the island have been greatly altered and disturbed, this species may have become rare because of loss of preferred habitat. Fourteen mōhihi vines were found along transects in `Ōla`a Forest in areas below 1,250 m (4,100 ft) elevation, primarily in the Koa Unit and outside the Pu`u Unit exclosure (Unit C) (Fig. 6). Only one mōhihi vine was seen within the Small Tract. Flowers were noted on several plants in the spring (March). *Stenogyne*

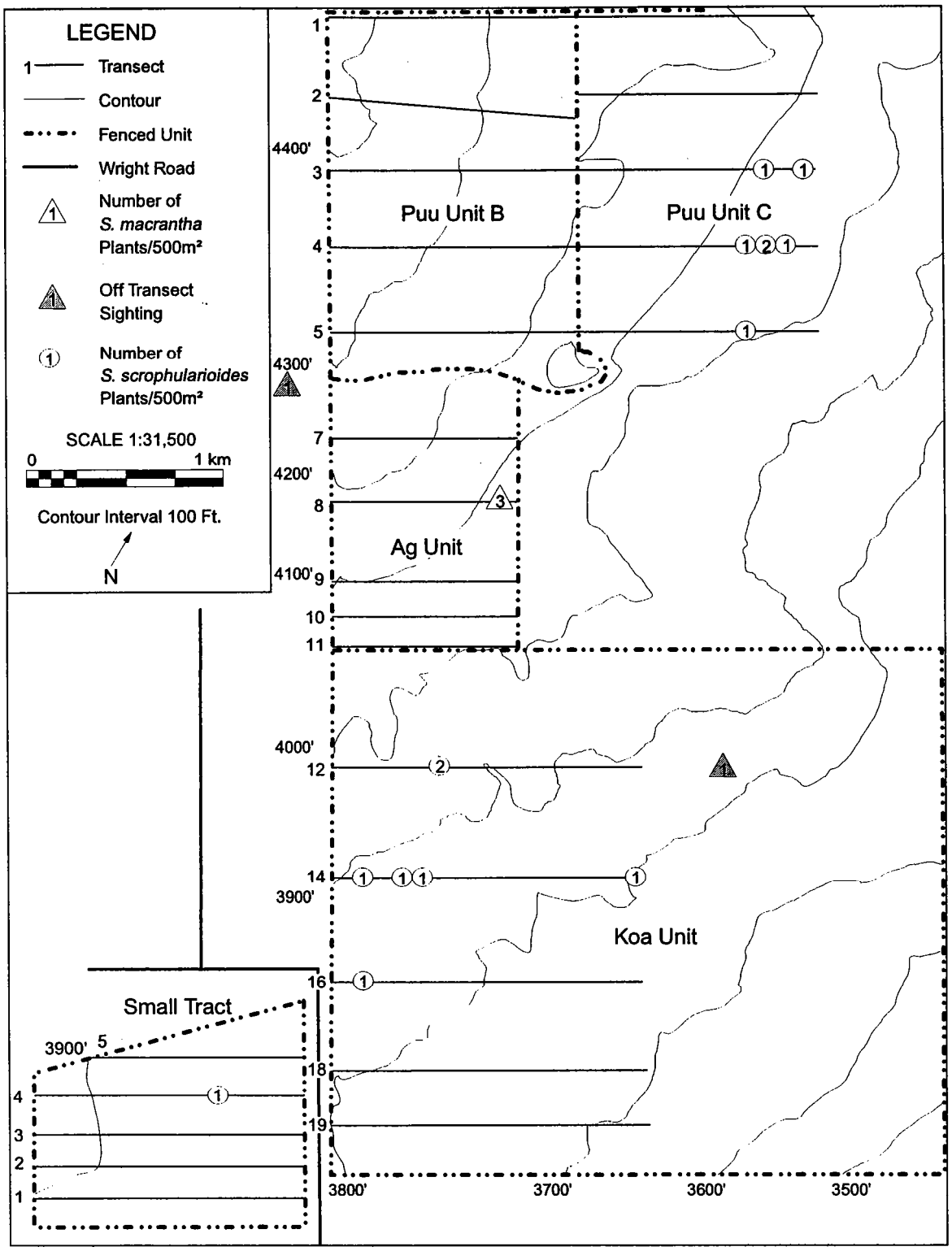

Figure 6. Distribution of *Stenogyne macrantha* and mōhihi (*Stenogyne scrophularioides*) along transects in five units of 'Ōla'a Forest, Hawaii Volcanoes National Park.

scrophularioides was not identified during Jacobi and Warshauer's `Ōla`a survey 23 years ago (1975), but Anderson *et al.* (1988a) observed the species at six sites in `Ōla`a, corresponding to areas where plants were seen in the present survey (Koa Unit and Pu`u Unit C). The species was not listed on earlier Park checklists (Fosberg 1966; Fagerlund and Mitchell 1944). Within the Park, the species appears to be restricted to `Ōla`a Forest. In the recent past, *Stenogyne scrophularioides* has been observed in forests near the Park, particularly Kīlauea Forest (Clarke *et al.* 1982). Threats to this species are not well known.

Pōpolo kū mai (*Phytolacca sandwicenis*) - A large sprawling herb, pōpolo kū mai is a member of the pokeweed family (Phytolaccaceae). This handsome plant has large oblong to elliptic, succulent leaves and terminal inflorescences of rose-pink or white flowers followed by clusters of shiny, dark purple, ribbed berries. Because it prefers open sites in wet forests, such as fencelines, pōpolo kū mai is sometimes mistaken for a non-native weed. Pōpolo kū mai is native to the five largest Hawaiian Islands, where it grows in wet to mesic forests above 680 m (2,240 ft) elevation (Wagner *et al.* 1990). More than 100 years ago, Hillebrand (1981) considered this a common species of the lower forests. Fifty years ago, Degener (1946) rated pōpolo kū mai as uncommon in higher elevation forests. Although widely distributed, the species appears to have become rare in recent years, particularly on O`ahu. Currently considered a "species of special concern" (U. S. Fish and Wildlife Service 1997), pōpolo kū mai is not likely to be proposed as endangered until much more data on its distribution and abundance are available.

During the survey of `Ōla`a Forest in 1992-94, ten pōpolo kū mai plants were seen at nine sites along transects in the Koa and Ag Units (Fig. 7). One additional plant was growing on the fence line near the northwestern corner of the Pu`u Unit. Although much of the surveyed area appeared to be suitable habitat for the species, pōpolo kū mai was found only once above 1,230 m (4,050 ft) elevation, and was never observed in the pig-disturbed forests outside exclosures. Jacobi and Warshauer (1975) rated pōpolo kū mai as uncommon on the edge of closed `ōhi`a lehua forest and rare in open `ōhi`a forests of the western `Ōla`a Tract. Anderson *et al.* (1988a) did not map pōpolo kū mai as a rare species during their survey. Although it is not possible to compare numbers of pōpolo kū mai in `Ōla`a observed during different surveys, the species may have disappeared from the Small Tract since Jacobi and Warshauer found it there 23 years ago. The species is known from forests adjacent to and near `Ōla`a, such as Pu`u Maka`ala NAR (The Nature Conservancy 1989) and Kīlauea Forest (Clarke *et al.* 1982). Outside `Ōla`a Forest, pōpolo kū mai has been found within the Park only at Kīpuka Kī (Fosberg 1966), where it has not been observed in more than 30 years and has likely been extirpated by past feral and domestic animal activity.

Schiedea diffusa - *Schiedea diffusa* is a climbing vine in the pink family (Caryophyllaceae); the members of this endemic genus have no known Hawaiian or common name. A relatively inconspicuous plant in dense forest, this *Schiedea* has shiny, narrow, opposite leaves and large open inflorescences of tiny green and purple flowers. The species is known from wet forests above 915 m (3,000 ft) elevation on eastern Moloka`i, East Maui,

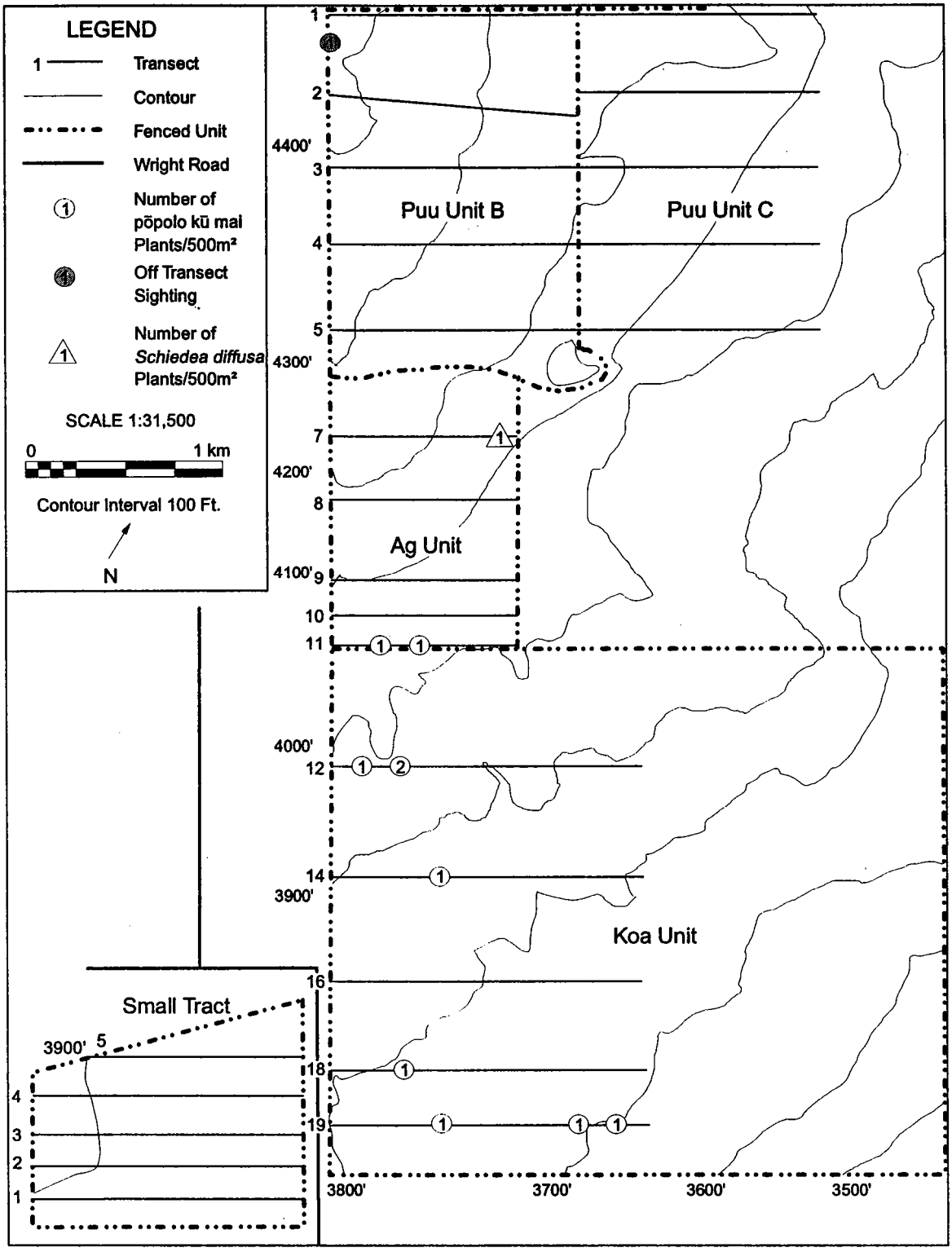

Figure 7. Distribution of pōpolo kū mai (*Phytolacca sandwicensis*) and *Schiedea diffusa* along transects in five units of 'Ōla'a Forest, Hawaii Volcanoes National Park.

and Hawai`i. *Schiedea diffusa* has been collected at only two Hawai`i Island sites in the last 85 years: the Kohala Mountains in 1911 and `Ōla`a Forest in 1987 (Wagner *et al.* 1990; L. Katahira, pers. comm 1987). The reasons for the rarity of this species are unknown, but plants propagated in a greenhouse are susceptible to alien insects, such as scale. Only one *Schiedea diffusa* was found along transects in the study area of `Ōla`a Forest at a site near the eastern fence of the Ag Unit (Fig. 7); this is the same individual first discovered by Larry Katahira in 1987 (Katahira and Taylor sn, BISH). The vine has persisted at this site for more than eight years. Flowers were noted once in February, and dry capsules were seen in the summer (July) of two consecutive years. Despite its successful production of seeds, which appear to readily germinate in the greenhouse, no young plants or progeny have been observed nearby. *Schiedea diffusa* is currently known from no other sites within the Park or elsewhere on the island.

Species of Concern Not Found in `Ōla`a Forest in 1992-94 - Three additional rare plant species have been collected or reported in `Ōla`a Forest in the recent past: a fern (*Asplenium schizophyllum)*, ānini (*Eurya sandwicensis*), and `ohe (*Joinvillea ascendens*). All three were included as category 2 candidates on a recent listing of species for review as threatened and endangered species of Hawai`i (U. S. Fish and Wildlife Service 1990), and they are currently considered "species of special concern" (U. S. Fish and Wildlife Service 1997).

A terrestrial or epiphytic fern endemic to the Hawaiian Islands, *Asplenium schizophyllum* has no specific common name, but belongs to a family (Aspleniaceae) known elsewhere as spleenworts. This fern is distinctive among the approximately 20 Hawaiian species of *Asplenium* because of its finely dissected fronds with very narrow, linear ultimate segments (Wagner and Wagner 1992). A century ago, the species (then known as *A. dissectum*) was thought to be confined to the islands of Hawai`i and Kaua`i (Hillebrand 1981), but was subsequently found on Maui and O`ahu (Robinson 1913). This *Asplenium* was not among the few ferns originally recommended as rare and endangered plants of Hawai`i 20 years ago (Fosberg and Herbst 1975), but it is now considered "threatened to very rare" by Wagner (1995).

While no *Asplenium schizophyllum* plants were found in the `Ōla`a Forest during the current survey, the species was collected in the areas now within the Koa Unit and Small Tract during the early 1980s (P.Higashino, pers. comm. 1987). As the taxonomy of the Hawaiian ferns is currently undergoing revision and concepts of species in large genera like *Asplenium* have changed in the last decade (Wagner and Wagner 1995), it would be desirable to have experts examine specimens from `Ōla`a identified as this species. This rare fern has also been reported from forests near `Ōla`a, such as Kīlauea Forest and Keauhou Ranch (Clarke *et al.* 1982). Future surveys and botanical work in `Ōla`a, particularly in the eastern half of the Koa Unit outside the current study area, should include this fern on any list of target rare plants for which to search. The fern has not been reported from any other sites within Hawaii Volcanoes National Park (Fosberg 1966; Herat and Herat 1975).

A small tree or shrub in the tea family (Theaceae), ānini (*Eurya sandwicensis*) is endemic to the five largest Hawaiian Islands, where it inhabits mid-elevation mesic to wet forests. The shrub has conspicuously toothed, narrow leaves with reddish veins, and bears in its leaf axils small yellow to cream-colored flowers and purple berries (Wagner *et al.* 1990). Although a century ago ānini was "not uncommon" in Hawai`i forests (Hillebrand 1981), the species appeared on early lists of potentially endangered Hawaiian plants as "rare to very rare" (Fosberg and Herbst 1975). No ānini plants were found during the 1992-94 survey of `Ōla`a Forest, but the species was formerly known from the area. Lani Stemmermann (pers. comm.1987) reported the plant from `Ōla`a Small Tract in the 1980s, and the Degeners collected ānini in 1967 along the southern fence line between `Ōla`a Tract and the adjacent pasture, near the area now known as the Koa Unit (Degener and Degener #31,552; HAVO Herbarium). Areas of both these sightings were searched unsuccessfully several times before and during the current study. Another older specimen of ānini (1942) in the Park Herbarium is from Keakealani School on Haunani Road, approximately two miles south of `Ōla`a Forest in Volcano Village (Fagerlund, Mitchell, and Horner #169). Although ānini has been recently documented from Pu`u Maka`ala NAR (The Nature Conservancy 1989), adjacent to `Ōla`a Forest, previous surveys of the Park's `Ōla`a Forest (Jacobi and Warshauer 1975, Anderson *et al.* 1988a) failed to locate the species. The current status of ānini in `Ōla`a is unknown; if the species is extant in the protected parts of `Ōla`a Forest, it is extremely rare.

Ānini has also been collected at one other site in the Park. More than 50 years ago, Fagerlund and Mitchell (1944) found the species to be "infrequent in wet forest north of Makaopuhi Crater" on Kīlauea's East Rift. Subsequently, this area has undergone much geological change, and extensive lava flows from several sustained eruptions have destroyed expanses of wet forest of the upper East Rift (Holcomb 1987). Two recent systematic surveys of East Rift vegetation (Anderson *et al.* 1988b; Pratt et al. 1998) and an intensive search of protected pit craters in these forests (Belfield 1998) failed to find ānini. Ānini may have been lost from the lower elevation forests of the Park that were originally within its range.

`Ohe (*Joinvillea ascendens* subsp. *ascendens*) is a large grass-like herb in the joinvillea family (Joinvilleaceae). The species is indigenous to Hawai`i and other islands of the Pacific; Hawaiian `ohe plants are placed in an endemic subspecies. In the Hawaiian Islands, `ohe occurs in wet forest and along streams at low to middle elevations on the five largest islands (Wagner *et al.* 1990). Hillebrand (1981) considered the species rare a century ago. Fosberg and Herbst (1975) rated the subspecies as depleted and restricted in range, and included it in their list of potentially endangered Hawaiian plant species. Despite its relatively wide distribution, `ohe remains rare on Hawai`i Island, perhaps because little low-elevation forest remains undisturbed.

`Ohe was not observed during the 1992-94 `Ōla`a survey, nor was it found in earlier systematic surveys of `Ōla`a Forest (Jacobi and Warshauer 1975; Anderson *et al.* 1988a).

However, `ohe was reported from the north-central part of `Ōla`a Forest (Large Tract) in the early 1980s, where it was seen during a reconnaissance prior to exclosure selection (L. Katahira, pers. comm. 1995). The species has not been confirmed from the adjacent Pu`u Maka`ala NAR (The Nature Conservancy 1989). `Ohe was not listed on earlier Park checklists (Fosberg 1966, 1975) and is not known from any Park sites outside `Ōla`a. The species has not been observed in the Park's East Rift forests (Anderson *et al.* 1988b; Pratt et al. 1998), although it was formerly found in forests of Kahauale`a and Wao Kele o Puna east of the Park (Char and Lamoureux 1985). If `ohe is extant within the Park, it may be restricted to the unprotected part of `Ōla`a Forest east of the fenced exclosures.

Rare Plant Species

In addition to endangered plants and species of special concern, at least fifty other plant species are rare in Hawaii Volcanoes National Park (National Park Service 1996). These rare species are often sensitive to disturbance, and some of them may require intensive management to prevent their eventual disappearance from the Park. Other species among the Park rarities may be naturally rare or uncommon because of range limitations or a lack of suitable habitat. Loss of any naturally occurring species results in a decrease in biodiversity and diminishment of stability for Park ecosystems. `Ōla`a Forest is habitat for at least eighteen rare plant species; these are primarily trees and shrubs, but also include orchids, vines, a fern vulnerable to pig feeding, and several lobelioids.

Orchids - Two of the three orchids endemic to the Hawaiian Islands occur within Hawaii Volcanoes National Park and were found along transects during the 1992-94 `Ōla`a survey. Jewel orchid or honohono (*Anoectochilus sandvicensis*) is a terrestrial herb with creeping stems, thin shiny green leaves, and attractive pale green to yellow flowers borne in terminal spikes. The species is distributed in wet forests on all the Hawaiian Islands except Ni`ihau and Kaho`olawe (Wagner *et al.* 1990). This orchid is rare on Hawai`i Island, but is more frequently seen on Maui and Moloka`i (pers. obs.) and was previously locally common on O`ahu (Fosberg 1969) . Jewel orchid was found at only one site within `Ōla`a Forest during the current survey, approximately 1 km from the western edge of the Koa Unit on the southernmost transect (Fig. 8). Because of the orchid's creeping habit, it was not possible to distinguish individual plants at this site, but the orchid was robust and covered an area greater than 1 m^2. When revisited in 1998, the orchid covered an area greater than 3 x 5 m. Flowers were observed on the jewel orchid in September and fruits were present in December. Jewel orchids were not observed by either Jacobi and Warshauer (1975) or Anderson *et al.* (1988a) during their surveys of `Ōla`a. The plant was not collected from the adjacent Pu`u Maka`ala NAR during a recent survey (The Nature Conservancy 1989). The only other known collections and sightings of this orchid in the Park were made near Nāpau Crater and Kāne Nui o Hamo (Fagerlund and Mitchell 1944; Fosberg 1966; HAVO Herbarium), where the orchid persisted in 1995 (Pratt *et al.* 1998).

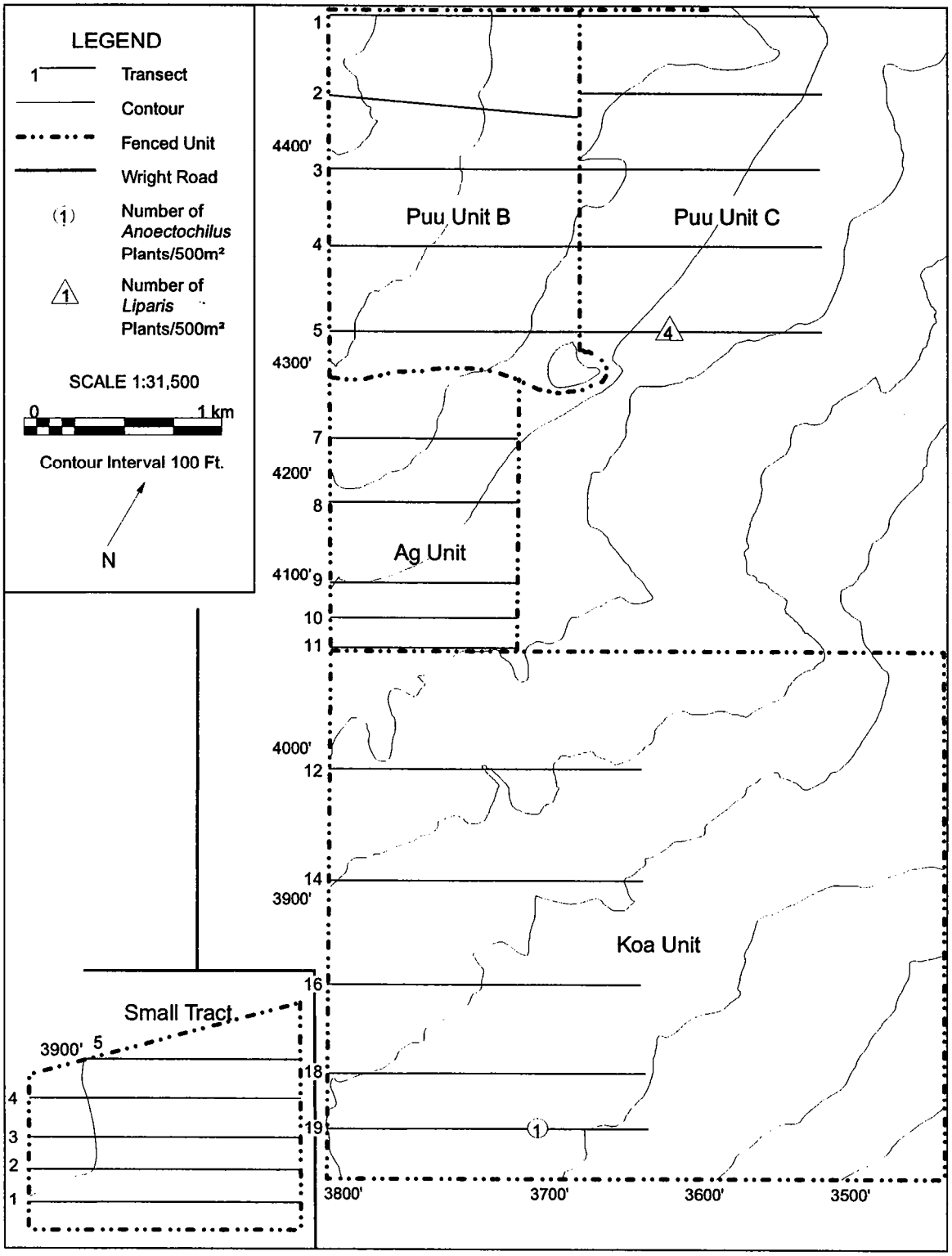

Figure 8. Distribution of jewel orchid (*Anoectochilus sandvicensis*) and 'awapuhi a Kanaloa (*Liparis hawaiensis*) along transects in five units of ʻŌlaʻa Forest, Hawaii Volcanoes National Park.

`Awapuhi a Kanaloa or twayblade (*Liparis hawaiensis*) is an herb with few (often two) large fleshy leaves and tiny pale green to white flowers; this orchid may be terrestrial or epiphytic. `Awapuhi a Kanaloa has a distribution similar to that of jewel orchid, but in addition to wet forests, it also occurs in bogs and mesic forests (Wagner *et al.* 1990). Only four plants were found in `Ōla`a Forest during the current survey; these were at one site in the lower part of Unit C outside the Pu`u Unit exclosure (Fig. 8). These small orchids were epiphytic on an `ōhi`a lehua bole about 1 m from the ground. Very inconspicuous, the orchids were noticed because they had persistent capsules in December. `Awapuhi a Kanaloa was also observed during earlier surveys of `Ōla`a. Jacobi and Warshauer (1975) found the orchid epiphytic on tree fern trunks within the koa forest now enclosed by the Koa Unit fence and in open `ōhi`a lehua forest of the Small Tract. In the current survey, the koa forest was outside the study area, and no orchids were found in Small Tract. Anderson *et al.* (1988a) observed `awapuhi a Kanaloa at four `Ōla`a sites: in Unit C east of the Pu`u Unit, in the area now enclosed by the Koa Unit, and at two unprotected sites east of the Ag Unit. Based on these past sightings, it is likely that this species persists at a number of `Ōla`a sites east of the area surveyed in 1992-94. Because of its small size, the orchid may be overlooked in the dense rain forest vegetation. Elsewhere in the Park, `awapuhi a Kanaloa has been previously collected in wet forests near Nāpau Crater (Fagerlund and Mitchell 1944; Fosberg 1966), but recent surveys of this area have failed to locate the orchid (Anderson *et al.* 1988b; Pratt *et al.* 1998; Belfield 1998). The orchid may also persist in forests near Kīlauea Iki and Keanakāko`i, where it has been observed within the last decade (pers. obs.).

Rare Vines - Two endemic vines were found to be rare in `Ōla`a. Kilioe (*Embelia pacifica*) of the myrsine family (Myrsinaceae) is a climbing liana with conspicuously punctate leaves clustered toward branch ends and axillary inflorescences of small, greenish flowers. The vine is native to wet forests on all the main Hawaiian Islands except Ni`ihau and Kaho`olawe (Wagner *et al.* 1990), but does not appear to be common on any island. Only five kilioe vines were found along transects in `Ōla`a Forest. These were at one site on the lower transect of Unit C outside the Pu`u Unit, at two sites within the Ag Unit, and at two sites in the northern half of the Small Tract (Fig. 9). None of these plants was flowering or fruiting when found; they appeared to be relatively young vines. Kilioe has also been recently reported from the recently part of `Ōla`a east of the Ag Unit (T. Tunison, pers. comm. 1995). Kilioe was observed at two of the currently known sites 23 years ago; Jacobi and Warshauer (1975) found that kilioe was rare in the Small Tract and in forest later enclosed by the Ag Unit. They also sighted the vine on the far eastern boundary of `Ōla`a Forest, well outside the current study area. Anderson *et al.* (1988a) did not observe kilioe during their survey of `Ōla`a Forest. The only other known sites for this species in the Park are Kīpuka Puaulu, where kilioe was collected in the 1940s (Fagerlund and Mitchell 1944) and persisted 50 years later (Pratt *et al.* in prep.); Kīpuka Kī; and the Boundary Kīpuka of Kīlauea's East Rift (Higashino and Katahira #9803, HAVO Herbarium), an area now covered by lava and cinder fields. Threats to this terrestrial vine are not well understood, but the species is rarely seen with flowers or fruits.

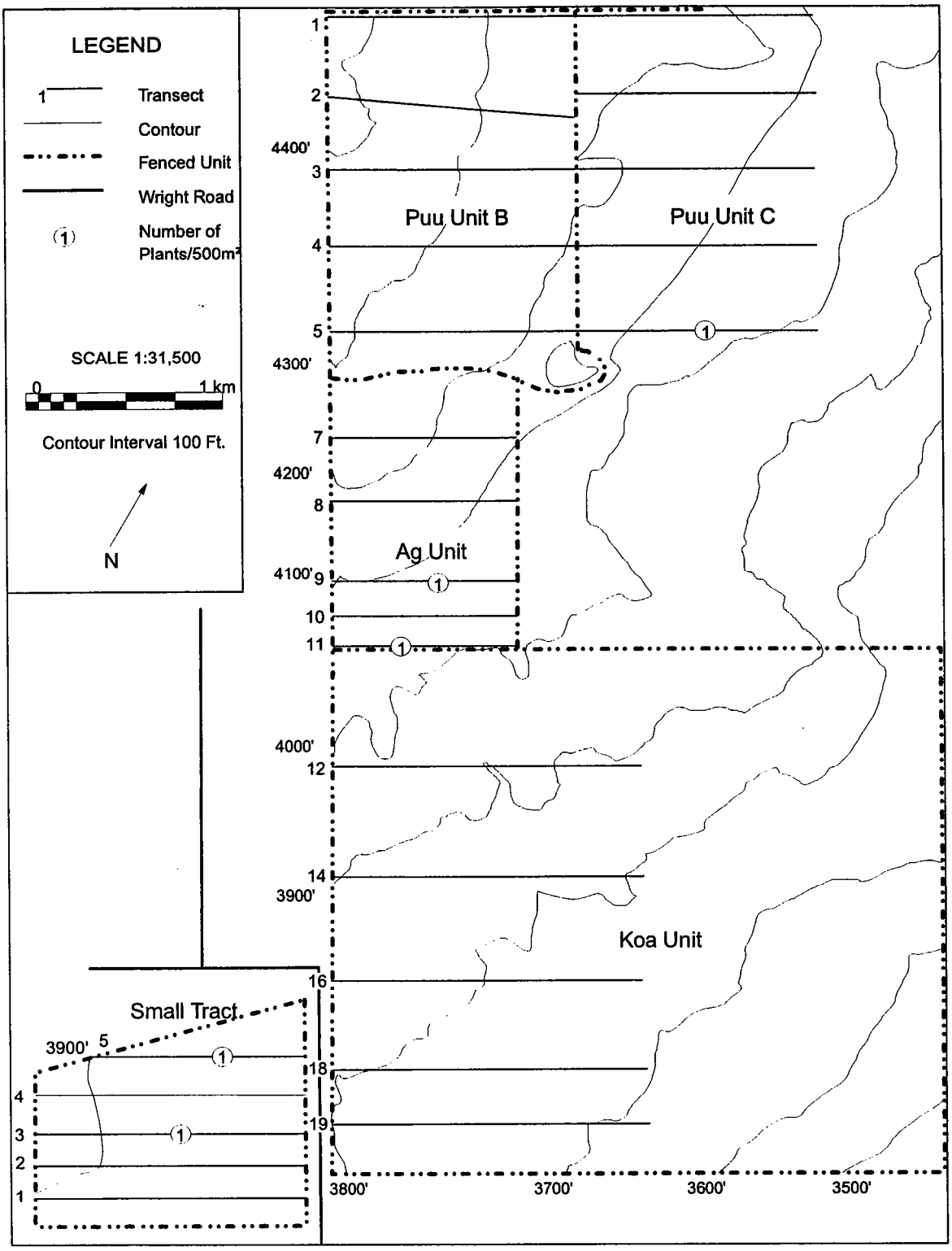

Figure 9. Distribution of kilioe (*Embelia pacifica*) along transects in five units of ʻŌlaʻa Forest, Hawaii Volcanoes National Park.

Pāwale (*Rumex giganteus*) of the buckwheat family (Polygonaceae) is typically a large liana in wet forest, but is more often a shrub in drier, more open forests and at subalpine sites. The species occurs on the islands of Moloka`i, Maui, and Hawai`i (Wagner *et al.* 1990), and on Hawai`i it is distributed in rainforest from Kulani around the southwestern slope of Mauna Loa to Hualālai (Degener and Degener 1971). In wet forest, pāwale climbs high into trees and has large, fleshy leaves, pendent inflorescences, and large clusters of red, papery capsules. At drier sites, shrubby pāwale are difficult to distinguish from the closely related *Rumex skottsbergii* (Wagner *et al.* 1990). Only 12 pāwale vines were found in `Ōla`a Forest during the 1992-94 survey and subsequent vegetation sampling for another project. Most of these (7) were on or near transects in the Koa Unit. Two pāwale were growing along the fence line of the Pu`u Unit, and three others were on the new fence line at the top of the outer Pu`u Unit C (now the New Unit) (Fig. 10). Most of the observed pāwale bore large clusters of fruits; no young plants were discovered. Pāwale was previously observed on the northern fence line of the Small Tract (Cuddihy 1985), but this individual was not relocated during the current survey. Jacobi and Warshauer (1975) found pāwale rarely in the area now enclosed as the Pu`u Unit, and rated the plant as rare to occasional in open-canopy forests of what is now the Koa Unit. Anderson *et al.* (1988a) did not see pāwale during their survey. The distribution and abundance of this species in `Ōla`a Forest does not appear to have greatly changed over the last 23 years. The species is known from several other Park sites, including montane dry communities on Mauna Loa (Fosberg 1966, 1969). Pāwale is rather common in cinder substrate at the "Devastation Area" near Kīlauea Iki, where the population has a high proportion of immature plants indicating a potential for expanding vegetative cover (Wright and Mueller-Dombois 1988).

Pala (*Marattia douglasii*) - Pala, the only native Hawaiian species in the mule's foot fern family (Marattiaceae), is a terrestrial fern with very large, tripinnate, fleshy fronds and succulent stipes shaped at the base like a mule's foot. A century ago, Hillebrand (1981) considered this fern common in forests of medium elevation; Hillebrand and other early authors also reported the use of the pala stipes and rootstocks as food by Hawaiians (Robinson 1912). Thirty years ago, the fern was considered rare in wet forests within Hawaii Volcanoes National Park (Fosberg 1966); a decade later pala was reported as rare in Park forests overall and uncommon in `Ōla`a Tract (Herat and Herat 1975). In the current survey, 83 pala were found along transects in `Ōla`a Forest, but the ferns were not evenly distributed in the study area. Very few pala were found inside the Pu`u Unit or within the Koa Unit, but they were widely distributed, if infrequent, along transects outside the Pu`u Unit (Unit C) (Fig. 11). Fifteen plants were seen in Small Tract; these were clustered in the southeast corner of the exclosure. Pala ferns were most abundant in the small Ag Unit between the Pu`u and Koa Units.

Pala ferns are known to be palatable to pigs, and may be a preferred food in some areas; the presence of large individuals is thought to be a sign of low pig activity (Herat and Herat 1975; Stone 1985). It is reasonable that the exclosures built earlier (Small Tract in 1981 and Ag Unit in 1988) would have more pala than the Koa Unit, which was built in 1990

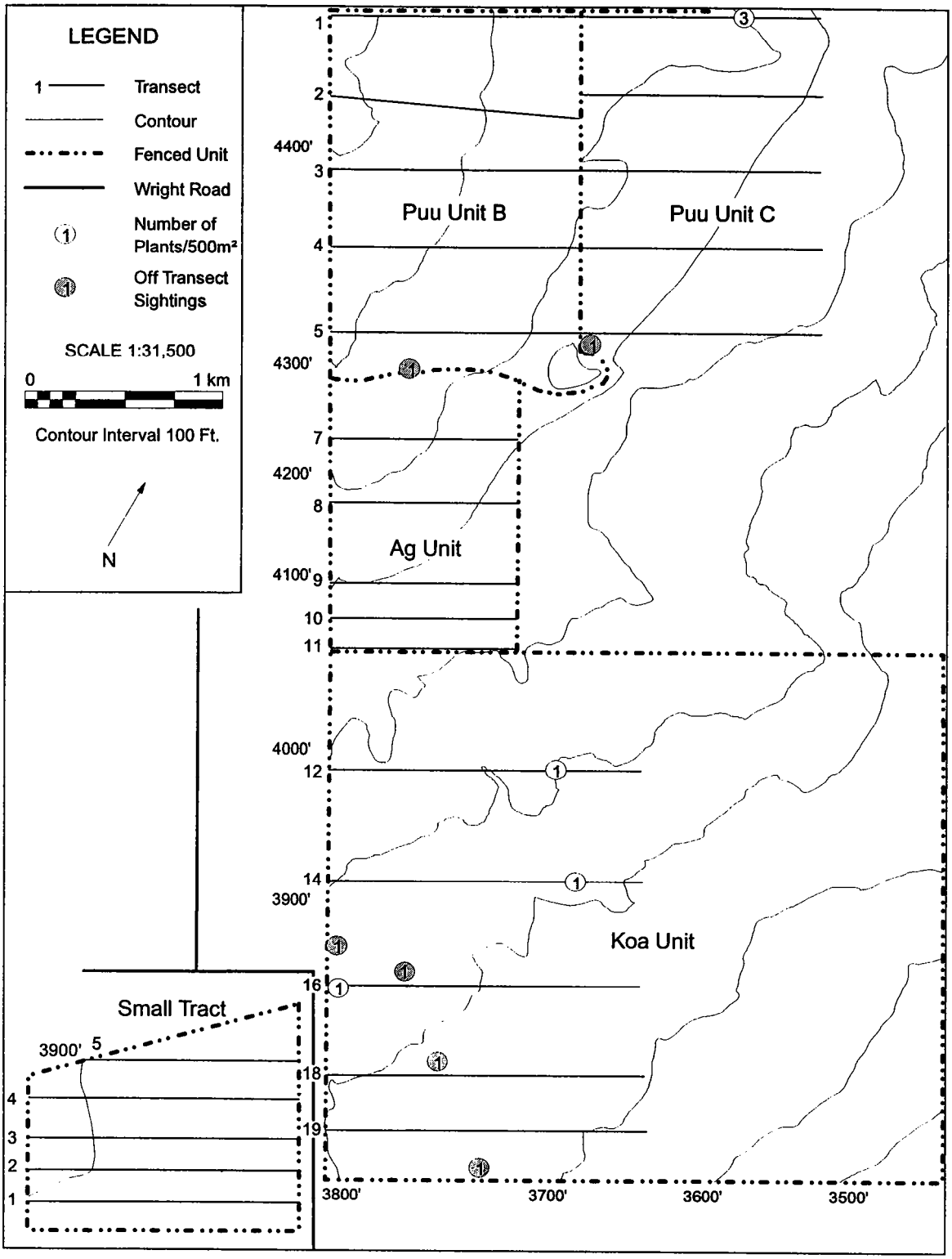

Figure 10. Distribution pāwale (*Rumex giganteus*) along transects in five units of ʻŌlaʻa Forest, Hawaii Volcanoes National Park.

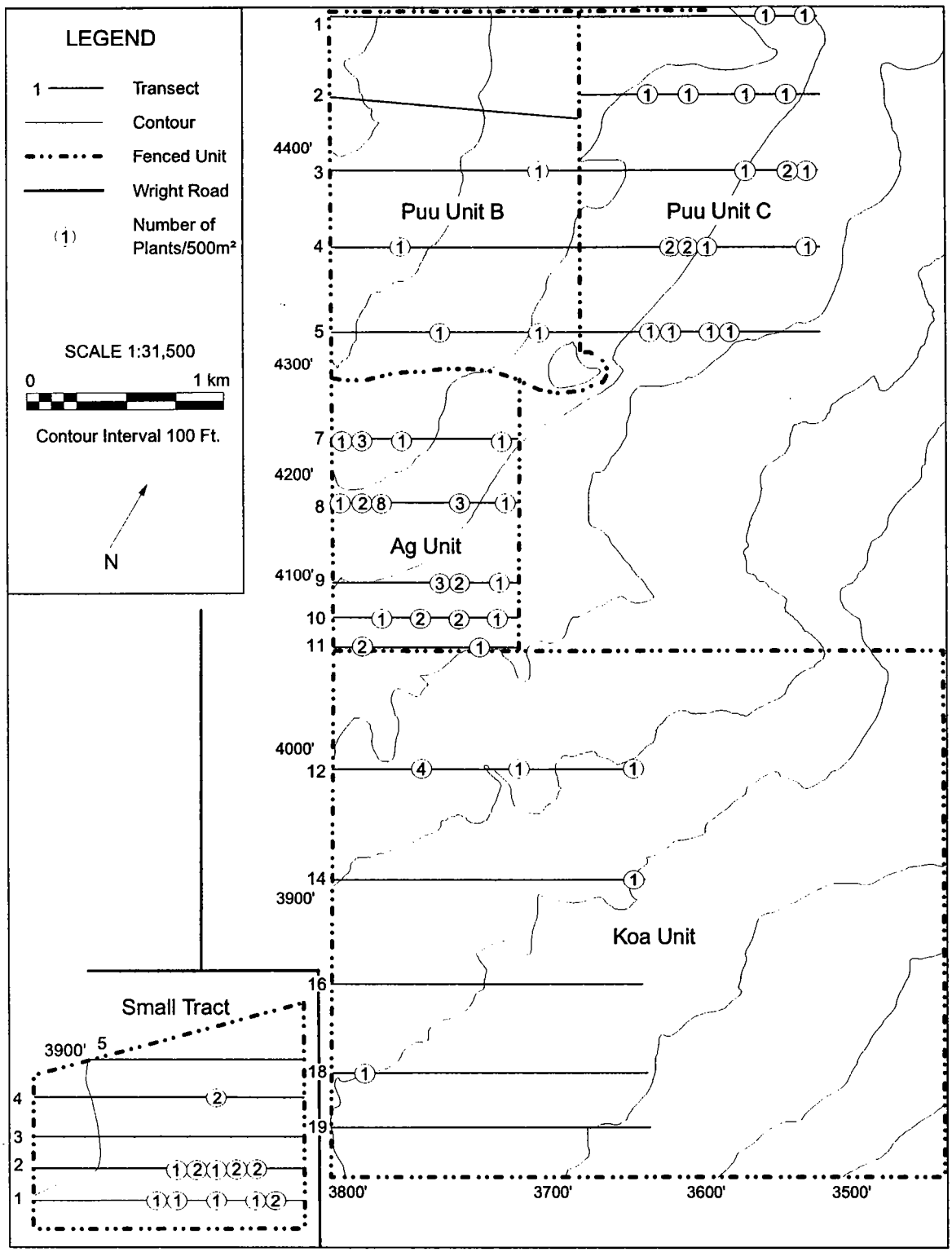

Figure 11. Distribution of pala *(Marattia douglasii)* along transects in five units of 'Ōla'a Forest, Hawaii Volcanoes National Park.

but declared pig-free only in 1994. The Pu`u Unit, however, was completed in 1985, and pala has had a decade to recover. It is possible that the fern's preferred habitat is at lower elevations, and the Pu`u Unit may be above its optimum elevational range. Jacobi and Warshauer (1975) rated pala as uncommon in most of the portions of `Ōla`a that they searched; they did not observe the fern in the southwestern corner of the tract corresponding to the western half of the Koa Unit. Perhaps because of high levels of pig activity, pala has been rare in this area for 23 years, and has not yet had time to recover from the depredations of feral pigs. Anderson *et al.* (1988a) did not map pala in their survey. Feral pigs are the primary source of ground disturbance and are likely the most serious threat to pala in unfenced areas. The Australian fern weevil (*Syagrius fulvitarsis*), a potentially serious pest on endemic `ama`u ferns (*Sadleria* spp.), is not known to attack pala (Swezey 1954); no insect damage was noted on pala during the current survey.

Lobelioids - In addition to the candidate endangered species *Trematolobelia grandifolia* (discussed above), there were five other lobelioids found within `Ōla`a Forest: three species of *Clermontia* and two *Cyanea*. The rarest of the three *Clermontia* was `ōha kēpau or *C. hawaiiensis*. This small tree has shiny, oblong leaves and attractive, curved, green flowers often tinged with purple. Flowers are typically borne in pairs on the axillary inflorescences, and develop into conspicuously ribbed, orange, fleshy fruits. Endemic to the Districts of Puna and Ka`ū on Hawai`i Island, this species was formerly a candidate for endangered species status (U.S. Fish and Wildlife Service 1976) but was later found to be too common to list as endangered. `Ōha kēpau also appeared on an early list of potentially endangered plants in the Park (Lamoureux 1976). During the current survey, only five `ōha kēpau plants were observed in `Ōla`a Forest; these were clustered at one site on a transect within the Ag Unit (Fig. 12). One tree was >2 m tall and bore flowers in July; the other four plants were 0.1-0.5 m tall and were likely progeny of the largest `ōha kēpau.

This species was not found in `Ōla`a Forest by Jacobi and Warshauer in 1975, although they did list one unidentified *Clermontia* that was rare in the Small Tract and Koa Unit. `Ōha kēpau was not noted during the 1988 survey of `Ōla`a (Anderson *et al.* 1988a) and was not seen during a recent survey of the adjacent Pu`u Maka`ala NAR (The Nature Conservancy 1989). Earlier this century, `ōha kēpau was "exceedingly plentiful" in the forests of Keauhou, "about three miles from the Volcano House" (Rock 1919b). Today, `ōha kēpau is very rare within the Park's `Ōla`a Forest, despite being relatively common in nearby forests prior to their disturbance by clearing (Clarke *et al.* 1982). This lobelioid has also been collected and observed at a few other sites within Hawaii Volcanoes National Park, including Kīpuka Puaulu, the Chain of Craters region, the Thurston Lava Tube vicinity, and East Rift forests (Fosberg 1966; Pratt *et al.* 1998; Belfield 1998). Unfortunately, `ōha kēpau has been lost from Kīpuka Puaulu (Pratt *et al.* in prep.), and is not abundant at any Park site.

Two other species of `ōha were relatively common within `Ōla`a Forest; both *Clermontia montis-loa* and *C. parviflora* were distributed throughout the five units of the study area (Fig. 13). The two species were combined for mapping purposes. It is very

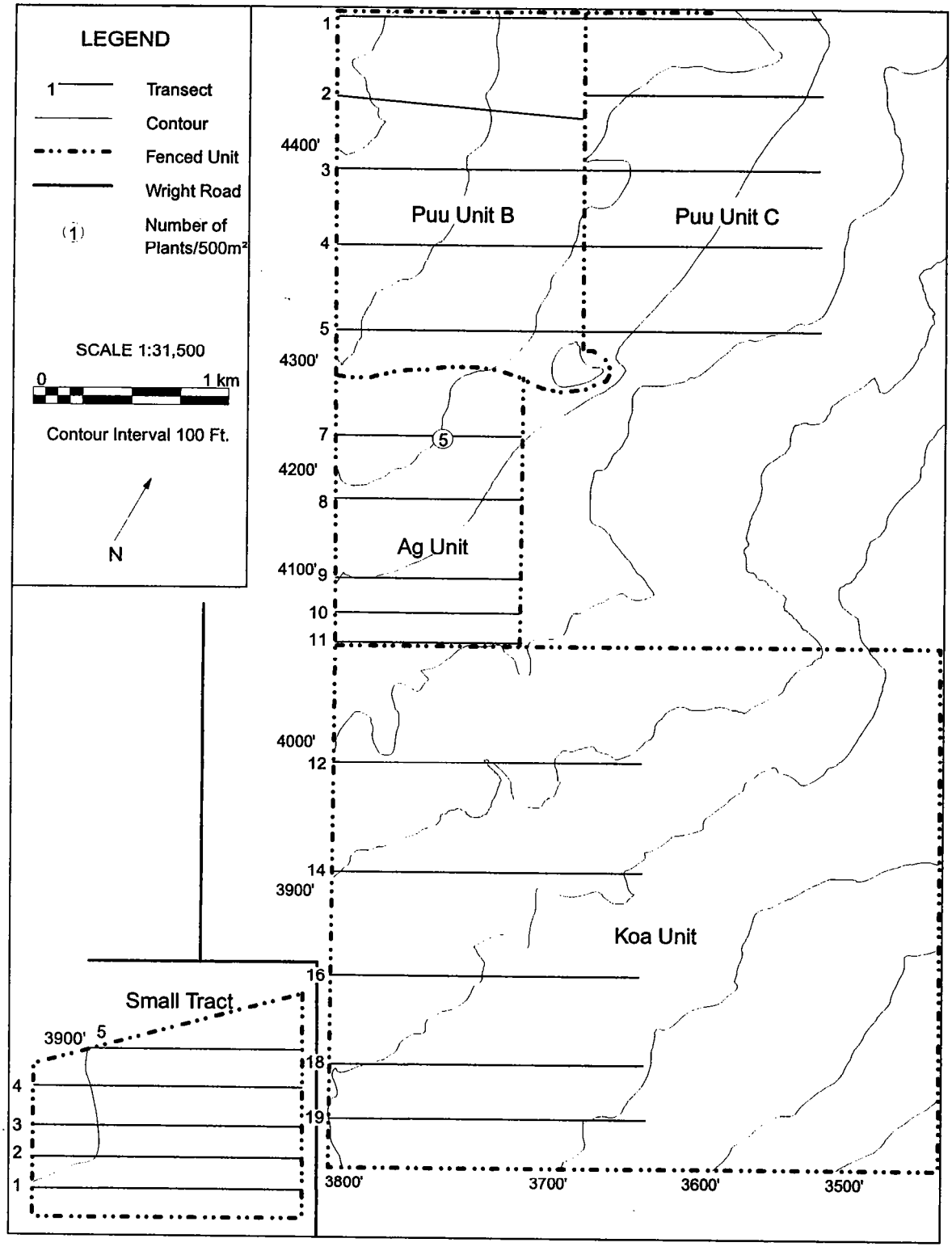

Figure 12. Distribution of 'ōhā kēpau (*Clermontia hawaiiensis*) along transects in five units of 'Ōla'a Forest, Hawaii Volcanoes National Park.

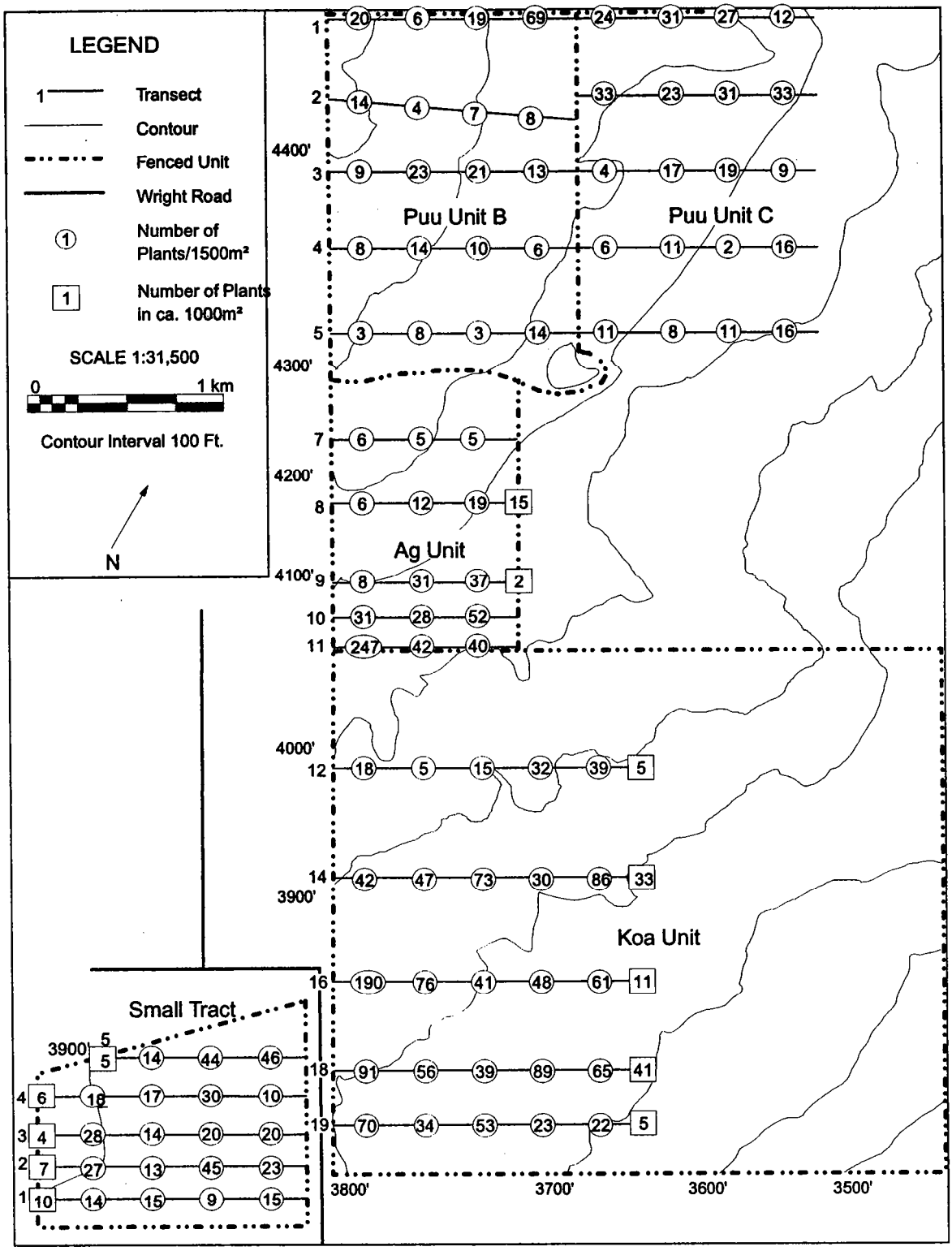

Figure 13. Distribution of 'ōhā (*Clermontia montis-loa* and *C. parviflora)* along transects in five units of 'Ola'a Forest, Hawaii Volcanoes National Park.

difficult to assign young `ōha plants to one or the other species, although they are quite different in appearance when mature. *Clermontia montis-loa* is a small tree with thick, dark green, narrow leaves and inflorescences of paired green and purple flowers. Its fruits are large, globose, orange berries. By contrast, *C. parviflora* or pāpa`a hekili is a shrub with thin, relatively broad leaves and small, white to purple flowers in clusters of four or more. Both are Hawai`i Island endemics found in windward rain forests, but *C. parviflora* is more abundant and widespread in the Park than is *C. montis-loa*. The two species are known to hybridize where their ranges overlap (Wagner *et al.* 1990; Lammers 1991). During this survey, these two *Clermontia* were most abundant in the Koa and Ag Units, where combined densities were 18/500 m^2 and 13/500 m^2, respectively. The Small Tract transects displayed *Clermontia* density of 8/500 m^2. Lowest *Clermontia* densities were found in and out of the Pu`u Unit (5/500 m^2 and 6/500 m^2), at the upper elevational reaches of the study area. At higher-elevation sites, *C. montis-loa* appeared to be more common than *C. parviflora*.

Both species were seen during Jacobi and Warshauer's 1975 survey of `Ōla`a; *Clermontia montis-loa* was rare in the areas now enclosed by the Koa and Ag Unit fences, and *C. parviflora* was common in the koa kīpuka and uncommon to occasional elsewhere in the eastern part of `Ōla`a. The two species were not mapped in the Anderson *et al.*(1988a) survey. Although it is difficult to directly compare the findings of the current survey with those of Jacobi and Warshauer, it appears that both *Clermontia* species have become more common in `Ōla`a Forest during the last two decades. *Clermontia parviflora* is also known from many other sites within the Park, including low elevation forests of the East Rift (Fosberg 1966; Pratt *et al.* 1998). *Clermontia montis-loa* is more restricted in range and has not been recently seen in Park forests outside `Ōla`a, although it was listed in earlier checklists as a Kīlauea wet forest epiphyte (Fagerlund and Mitchell 1944; Fosberg 1966).

Two species of *Cyanea* or hāhā were found within `Ōla`a Forest in addition to the previously discussed former candidate endangered *C. tritomantha*. *Cyanea pilosa* subsp. *longipedunculata,* which has no specific Hawaiian name, is a shrub with large, densely hairy leaves and long, pendent clusters of white to pink curved flowers. Both the species and subspecies are endemic to Hawai`i Island; the other subspecies (subsp. *pilosa*) is restricted to Mauna Kea and the Kohala Mountains (Wagner *et al.* 1990). The subspecies *longipedunculata* is distinguished by its very long inflorescence stalks or "peduncles"; this taxon was originally named a distinct species when first discovered near the Saddle Road in 1956 (Rock 1957). Like other lobelioids, this *Cyanea* is weak stemmed, somewhat succulent, and vulnerable to damage from feral pigs. Unlike *Clermontia*, species of *Cyanea* are typically terrestrial or very low epiphytes, increasing their vulnerability to ground disturbance.

In `Ōla`a Forest, *Cyanea pilosa* subsp. *longipedunculata* was not evenly distributed, but was concentrated in the Small Tract at 1,160 m (3,800 ft) elevation and in the area outside the Pu`u Unit (Unit C) at 1,250-1,280 m (4,100-4,200) ft (Fig. 14). Among the surveyed units, Small Tract supported the greatest numbers of *C. pilosa*; 81 plants were

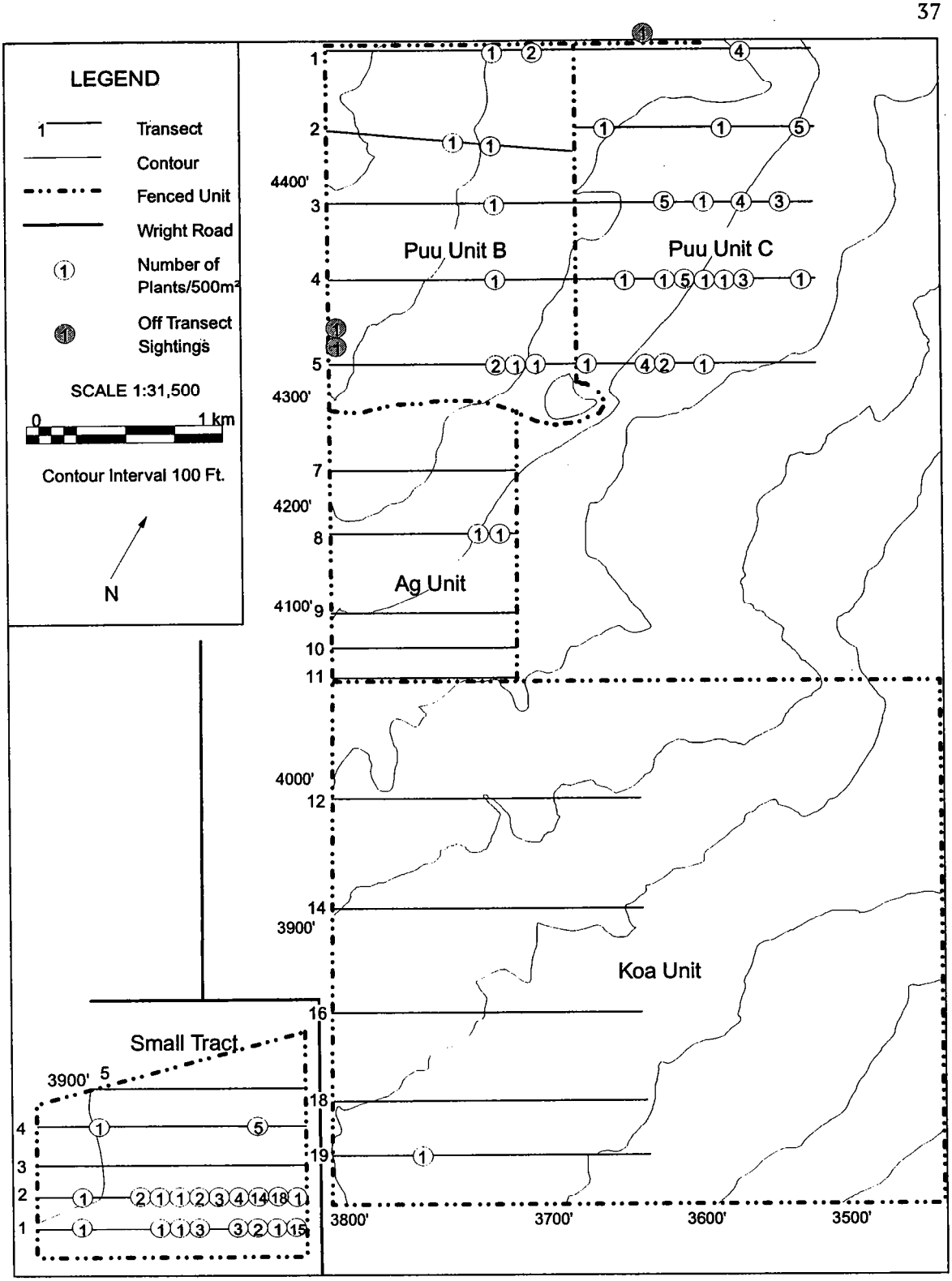

Figure 14. Distribution of hāhā (*Cyanea pilosa subsp. longipendunculata*) along transects in five units of 'Ōla'a Forest, Hawaii Volcanoes National Park.

counted along transects. These *Cyanea* were almost entirely in the southern part of the tract, on substrates of Kīlauea Volcano, just south of the Kīlauea/Mauna Loa contact (Holcomb 1987). Several size classes of *Cyanea* were present in the area, ranging from seedlings <10 cm tall to mature plants 1-2 m in height. Only one individual *Cyanea pilosa* subsp. *longipedunculata* was observed within the adjacent Koa Unit. There are few obvious differences in the habitat of the two areas, other than the recency of feral pig removal in the Koa Unit (1994). Likewise, few *Cyanea* were seen in the Ag Unit (2) or the Pu`u Unit (11), despite protection of the enclosed areas from pigs for a decade. After the Small Tract, the unprotected area east of the Pu`u Unit (Unit C) had the greatest number of *Cyanea pilosa* subsp. *longipedunculata* (45); these were frequently found on the lower two transects and at transect ends, implying that lower elevational sites were most suitable for this species. One possible factor in common outside the Pu`u Unit and in southern half of the Small Tract is a substrate of comparatively shallow soil over `ā`a (K. Harrington, pers. comm. 1999).

Jacobi and Warshauer (1975) considered this an uncommon species in the eastern part of what is now the Koa Unit and on the far eastern boundary of the forest; they noted only small shrubs to 1 m in height. Surprisingly, they did not encounter the species in the eastern half of the Small Tract. This *Cyanea* may have increased in numbers and undergone recovery in the 23 years since the Jacobi and Warshauer survey, at least in the Small Tract, where the forest has been pig-free for nearly 20 years. Anderson *et al.* (1988a) counted a total of 67 *Cyanea pilosa* subsp. *longipedunculata* on their transects; these plants were found primarily in the northeastern quarter of `Ōla`a Forest, outside the current study area.

Cyanea degeneriana was known by several other names in the past, including *C. floribunda, C. densiflora, C. pilosa* var. *densiflora, C. glabrifolia,* and *C. pilosa* var. *glabrifolia* (Wagner *et al.* 1990; Rock 1962). It is a small, usually unbranched shrub with leaves shiny green on top and whitish hairy beneath. Its curved, white to purple flowers and showy orange berries are borne in tight clusters close to the stem. This *Cyanea* is endemic to Hawai`i Island, where it grows in wet forests of the windward slopes (Wagner *et al.* 1990). During the 1992-94 `Ōla`a survey, this species was frequently encountered inside and outside the Pu`u Unit and in the Ag Unit. Sixty individuals were counted inside the Pu`u Unit, with a few additional plants noted on fence lines; a similar number (58) of plants was found within the Ag Unit. Forty-three plants were counted along transects outside the Pu`u Unit. Very few were observed in the northern part of the Koa Unit, and no plants were seen within Small Tract (Fig. 15). Unlike *C. pilosa* subsp. *longipedunculata*, this species appeared to be restricted to elevations above 1,190 m (3,900 ft).

Jacobi and Warshauer (1975) also noted a *Cyanea*, which they called *C. pilosa* but distinguished from *C. longipedunculata*, as a uncommon species in the areas now enclosed as the Pu`u and Ag Units. This plant may have been *C. degeneriana.* Anderson *et al.* (1988a) encountered only 10 *C. degeneriana* on their survey, primarily in the northern part of `Ōla`a Forest corresponding to the area outside and east of the Pu`u Unit. This contrast with the findings of the current survey suggests that numbers of this *Cyanea* have been increasing

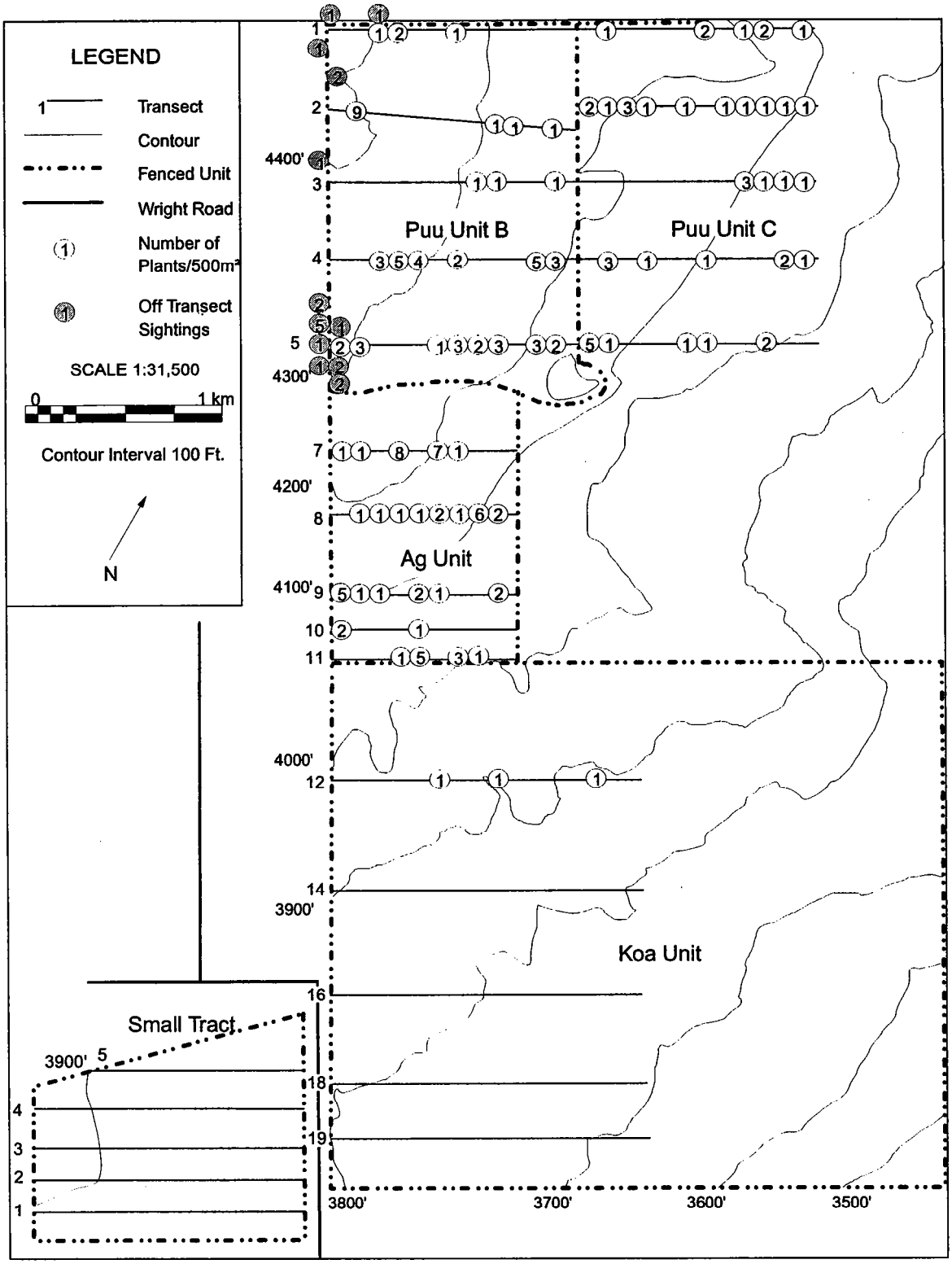

Figure 15. Distribution of hāhā (*Cyanea degeneriana*) along transects in five units of 'Ōla'a Forest, Hawaii Volcanoes National Park.

over the past few years. *Cyanea degeneriana* is also found at a few other Park sites outside `Ōla`a. The species was collected from forests of the East Rift more than 50 years ago, and plants have been recently observed at protected sites in these same forests (Belfield 1998; Pratt *et al.*1998). More than a decade ago, the species was collected from a site near Thurston Lava Tube (Santos sn, HAVO Herbarium); it is uncertain if any *Cyanea* remain in these forests. All the previously discussed species of *Clermontia* and *Cyanea* are negatively impacted by rats, which eat their berries, destroy flowers before fruits can form, and girdle fleshy stems during periods of dry weather. Slugs and non-native insects may also be threats to these lobelioids.

Rare Trees and Shrubs - At least ten species of native trees and shrubs are rare within `Ōla`a Forest, but the reasons for their rarity are not usually known. Some of these woody species may be naturally rare because `Ōla`a is on the edge of their natural ranges or because they have narrow ecological tolerances or are at a competitive disadvantage with other natives; others may have been negatively impacted by past feral pig disturbance. Other possible explanations of woody plant rarity are seed predation by non-native rats (*Rattus rattus* and *R.. exulans*) and competition with alien plant species that have invaded `Ōla`a Forest.

Pāpala (*Charpentiera obovata*) is a tree of the amaranth family (Amaranthaceae); it is endemic to the Hawaiian Islands (except Ni`ihau and Kaho`olawe), but is most common on O`ahu (Wagner *et al.* 1990). A shrubby, soft-wooded tree, pāpala may be distinguished from other related species by its stiff leaves with a pronounced marginal rib or thickening (Sohmer 1972). Found in both wet and mesic forests, pāpala has been observed in the Kohala Mountains and North Kona (Rock 1974), but is not a common plant on Hawai`i Island. During the current survey, 49 pāpala trees were found along transects within `Ōla`a Forest. These trees were seen primarily in the central part of the Small Tract (23) and in the southern third of the surveyed Koa Unit (25); only one pāpala was found in the unfenced area outside the Pu`u Unit (Unit C) (Fig. 16). Most of the `Ōla`a pāpala were mature trees, 5-6 m tall; many were decadent and in poor condition. A few pāpala saplings were noted on transects within the Small Tract, but no small seedlings were found. However, during another project in 1996-98, small pāpala plants that appeared to be seedlings and young trees <1 m tall were found in the upper half of Small Tract and the lower western corner of Koa Unit. It is likely that many more pāpala occur within the Small Tract and Koa Unit, as recent sightings have been made in areas between transects. Other past surveys have also reported pāpala in this part of `Ōla`a. Jacobi and Warshauer (1975) rated pāpala as uncommon in both the Small Tract and the area that later became the Koa Unit; they interpreted pāpala trees as relicts of a previous vegetation type formed under drier conditions. Anderson *et al.* (1988a) mapped 19 pāpala trees in the southwestern corner of the Koa Unit; they did not note the species elsewhere, although their survey covered the entire Large Tract, an area three times the size of the current study area. Outside `Ōla`a Forest, pāpala occurs in the Park only at Kīpuka Puaulu and Kīpuka Kī, where it has been out-planted (Zimmer 1982). More than 50 years ago pāpala was a natural component of Kīpuka Puaulu (Fosberg 1966).

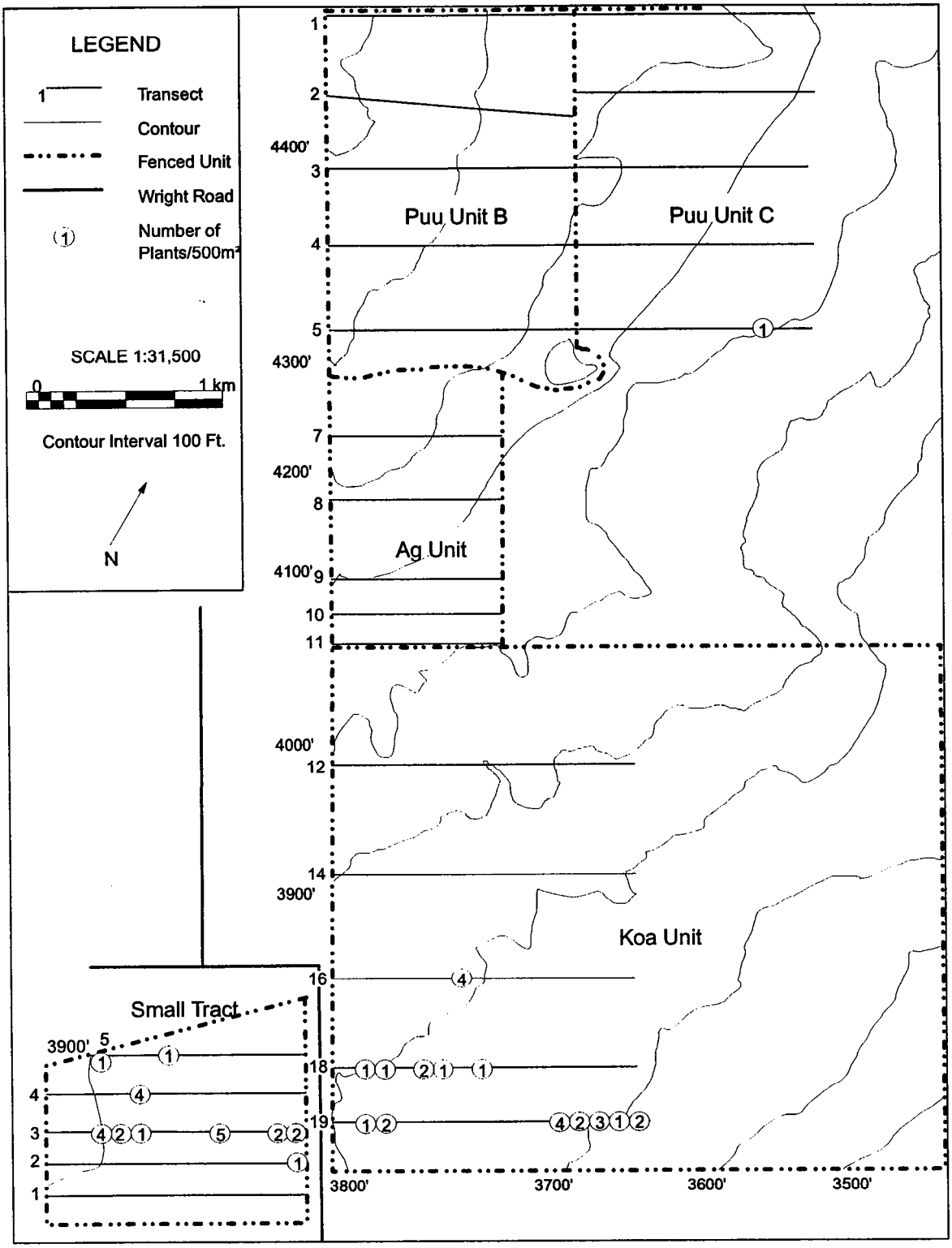

Figure 16. Distribution of pāpala (*Charpentiera obovata*) along transects in five units of ʻŌlaʻa Forest, Hawaii Volcanoes National Park.

Kāmakahala (*Labordia hirtella*) is a shrub in the logania family (Loganiaceae); this species is highly variable and may represent a species complex (Wagner *et al.* 1990). A number of older taxa have been consolidated into this species, including *L. baillonii*, previously thought to be a distinct island endemic (St. John 1936, 1973) and one of the endangered species of the Park (Lamoureux 1976). *Labordia hirtella* has large leaves, pale and hairy beneath, and conspicuous inflorescences of yellow flowers; the plant is somewhat larger than the more common *L. hedyosmifolia.* In the current treatment of the group, *L. hirtella* is a species of wet to mesic forests on the six largest Hawaiian Islands, and *L. hedyosmifolia* is a wet forest plant of Moloka`i, Lana`i, Maui, and Hawai`i (Wagner *et al.* 1990). During the 1992-94 survey of `Ōla`a Forest, these two species could not always be distinguished, so they were mapped together. Only 23 kāmakahala plants were seen widely scattered along transects and nearby fence lines; most occurred inside and outside the Pu`u Unit and in the southern extremes of the Small Tract and Koa Unit (Fig. 17). The rarity of the two *Labordia* species in `Ōla`a has not changed in the last 23 years; Jacobi and Warshauer (1975) considered *L. hedyosmifolia* and an unidentified *Labordia* rare to uncommon in most of the `Ōla`a forest types they searched. Within the Park, *Labordia hirtella* seems to be restricted to `Ōla`a Forest, but *L. hedyosmifolia* ranges to Kīlauea, Kīlauea Iki, and East Rift forests (Fosberg 1966).

`Aiea (*Nothocestrum longifolium*), a small tree of the nightshade family (Solanaceae), has widely spaced, lanceolate to oblong leaves; fragrant, greenish-yellow flowers borne in leaf axils; and elongated orange berries. The species is distributed on all the main Hawaiian Islands, except Ni`ihau and Kaho`olawe (Wagner *et al.* 1990). Formerly, a variety with hairy leaves was recognized as a rare Hawai`i Island endemic (St. John 1973); this was among the candidate endangered species in an early list of Park rarities (Lamoureux 1976). While no longer considered a candidate for endangered species status, this `aiea remains an uncommon plant in the Park. Only 38 `aiea trees were observed along transects in `Ōla`a Forest; almost half of these were concentrated in the lower half of the Ag Unit (Fig. 18). `Aiea trees were also scattered throughout the other four surveyed units, but very few individuals were found in Koa Unit or Small Tract. Flowers and fruits were noted on a few plants in the spring and summer. Jacobi and Warshauer (1975) also rated `aiea as a rare plant during their survey 23 years ago; as in the current survey, they did not find the tree in the western part of the Koa Unit. Anderson *et al.* (1988a) reported only 12 `aiea trees on their more widely-spaced transects; most of these were east of the current study area. Although uncommon in `Ōla`a Forest, this species of `aiea is even rarer elsewhere within the Park, where it is currently known only from Kīpuka Puaulu (Fosberg 1966) and Kīpuka Kī (Zimmer #13 and Clarke #15, HAVO Herbarium). More than 60 years ago, this `aiea was collected in forest near Nāpau Crater (Morley #174-H, HAVO Herbarium), but the tree has not been recently sighted in East Rift forests.

Pāpala kēpau (*Pisonia brunoniana*), a soft-wooded tree of the four o`clock family (Nyctaginaceae), occurs on O`ahu, Moloka`i, Lana`i, and Hawai`i and is also native to Australia, New Zealand, and islands of the South Pacific (Wagner *et al.* 1990). An attractive

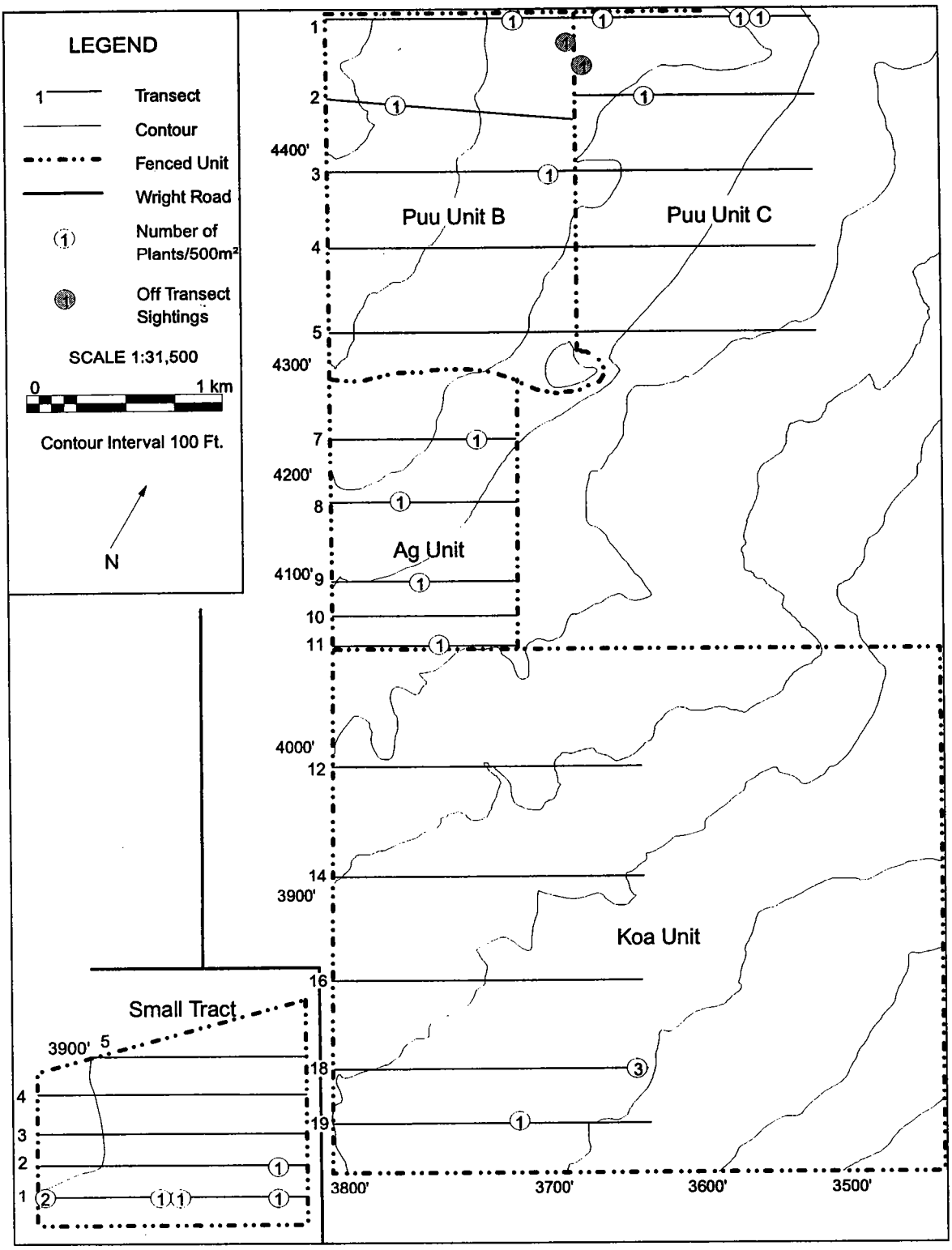

Figure 17. Distribution of kāmakahala (*Labordia hedyosmifolia* and *L. hirtella*) along transects in five units of 'Ōla'a Forest, Hawaii Volcanoes National Park.

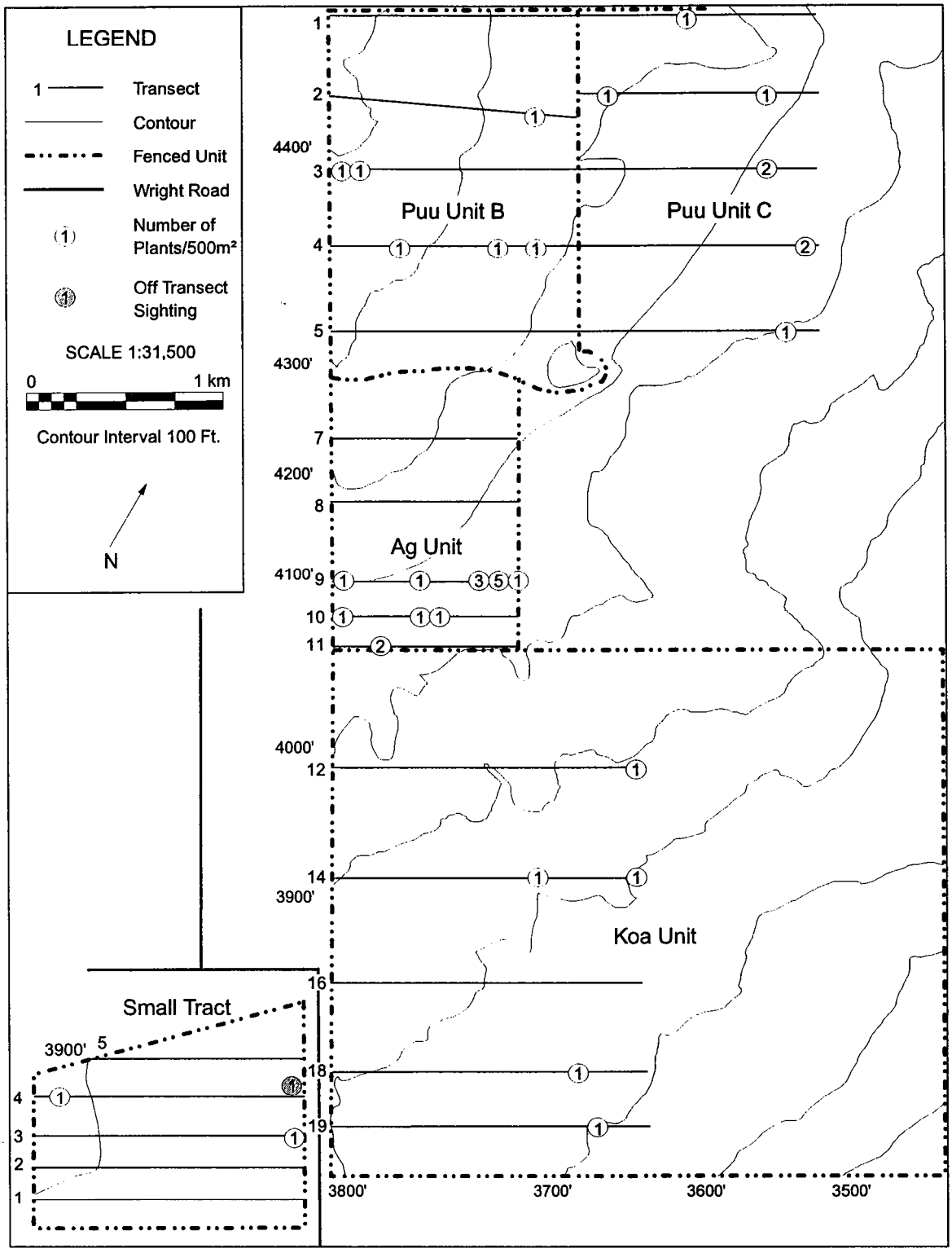

Figure 18. Distribution of 'aiea (*Nothocestrum longifolium*) along transects in five units of ʻŌlaʻa Forest, Hawaii Volcanoes National Park.

small tree with shiny, opposite to whorled leaves and open inflorescences of small pink, funnel-shaped flowers, pāpala kēpau has as its most unusual feature incredibly sticky, ribbed fruits. The species is uncommon on Hawai`i Island, where it is characteristic of dry to mesic forests on Hualālai, Mauna Loa, and sites near Waimea (Rock 1974). Only six pāpala kēpau trees were found along transects in `Ōla`a Forest; these were all within Small Tract, concentrated in the northern half of the exclosure (Fig. 19). A group of more than 20 large pāpala kēpau trees was seen off-transect near the eastern boundary fence of Small Tract. When this site was revisited in 1996, many pāpala kēpau seedlings were noted in a natural opening near the grove of mature trees. One other pāpala kēpau tree was noted on the Koa Unit fence line parallel to Wright Road; other individuals may be suspected in this area. Jacobi and Warshauer (1975) observed only two patches of pāpala kēpau in the Small Tract during their survey. Like pāpala, pāpala kēpau was considered to be a relict of an earlier drier vegetation type, rather than a typical element of rain forest vegetation. Anderson *et al.* (1988a) did not encounter pāpala kēpau on their survey transects. Elsewhere in the Park, pāpala kēpau is known from Kīpuka Puaulu (Fosberg 1966) and Kīpuka Kī.

Pilo kea (*Platydesma spathulata*) is a member of an endemic Hawaiian genus of the rue or citrus family (Rutaceae). A shrub or small tree, pilo kea is distributed in mesic to wet forest on the four largest Hawaiian Islands (Wagner *et al.* 1990), but achieves its greatest size and abundance on the island of Kaua`i (Stone 1962). The species is relatively uncommon on Hawai`i Island, where it has long been known from the Kohala Mountains (Rock 1974). The pilo kea of `Ōla`a is usually a shrub with large obovate leaves and fleshy, white flowers, followed by rounded, four-parted capsules borne in leaf axils. Pilo kea was very rare within `Ōla`a Forest in 1992-94; only 18 plants were found along surveyed transects (Fig. 20). Half of these were clustered on the eastern side of the surveyed area outside the Pu`u Unit (Unit C); the other pilo kea plants were widely scattered in the lower Pu`u Unit, Ag Unit, and Koa Unit. A few individuals of pilo kea were observed off-transect in the Koa Unit. No pilo kea plants were seen in the Small Tract during the current survey. Pilo kea may have become less common in `Ōla`a over the last 23 years, as Jacobi and Warshauer (1975) reported the species as a rare to uncommon element in all but one of the areas they searched. They noted pilo kea as a conspicuous plant of the shrub layer in closed forest now enclosed by the Ag Unit; by contrast the current survey found very few pilo kea in this area. The species also appears to have disappeared from the Small Tract over the last two decades. Anderson *et al.* (1988a) found only 14 pilo kea very sparsely distributed over the entire large tract of `Ōla`a Forest. The species is not known from any Park sites outside `Ōla`a. Reasons for the species' rarity are not understood.

Loulu is the Hawaiian name of a group of palms (family Arecaceae) native to the Hawaiian Islands and several other island groups of the tropical Pacific. The loulu of `Ōla`a (*Pritchardia beccariana*) is a tall, stately fan palm endemic to wet forests of windward Hawai`i Island. Formerly, the loulu near Volcano was known as var. *giffardiana* and was thought to be somewhat smaller and distinct from the typical variety common in the forest near Glenwood (Beccari and Rock 1921). Varietal distinctions are no longer recognized in

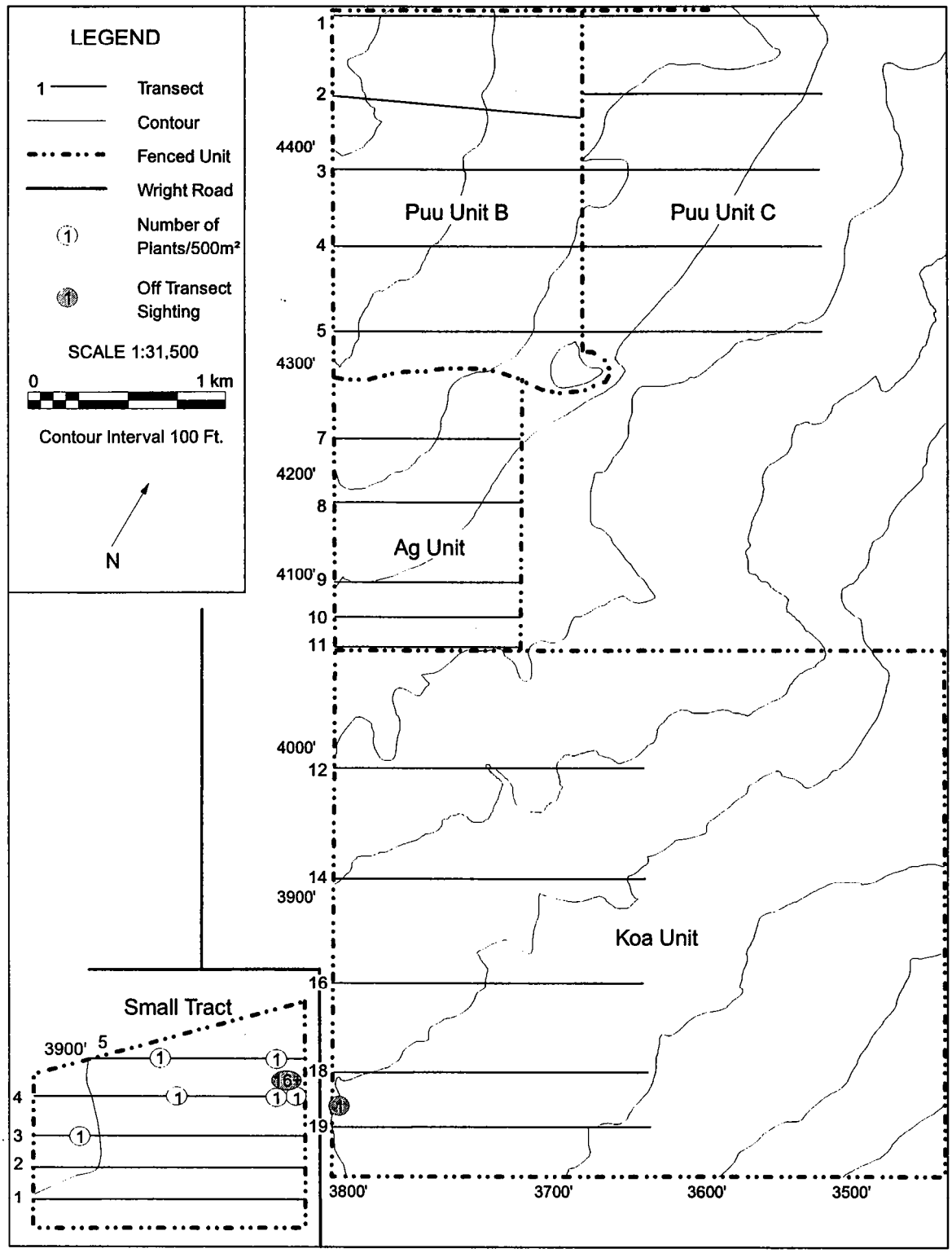

Figure 19. Distribution of pāpala kēpau (*Pisonia brunoniana*) along transects in five units of ʻŌlaʻa Forest, Hawaii Volcanoes National Park.

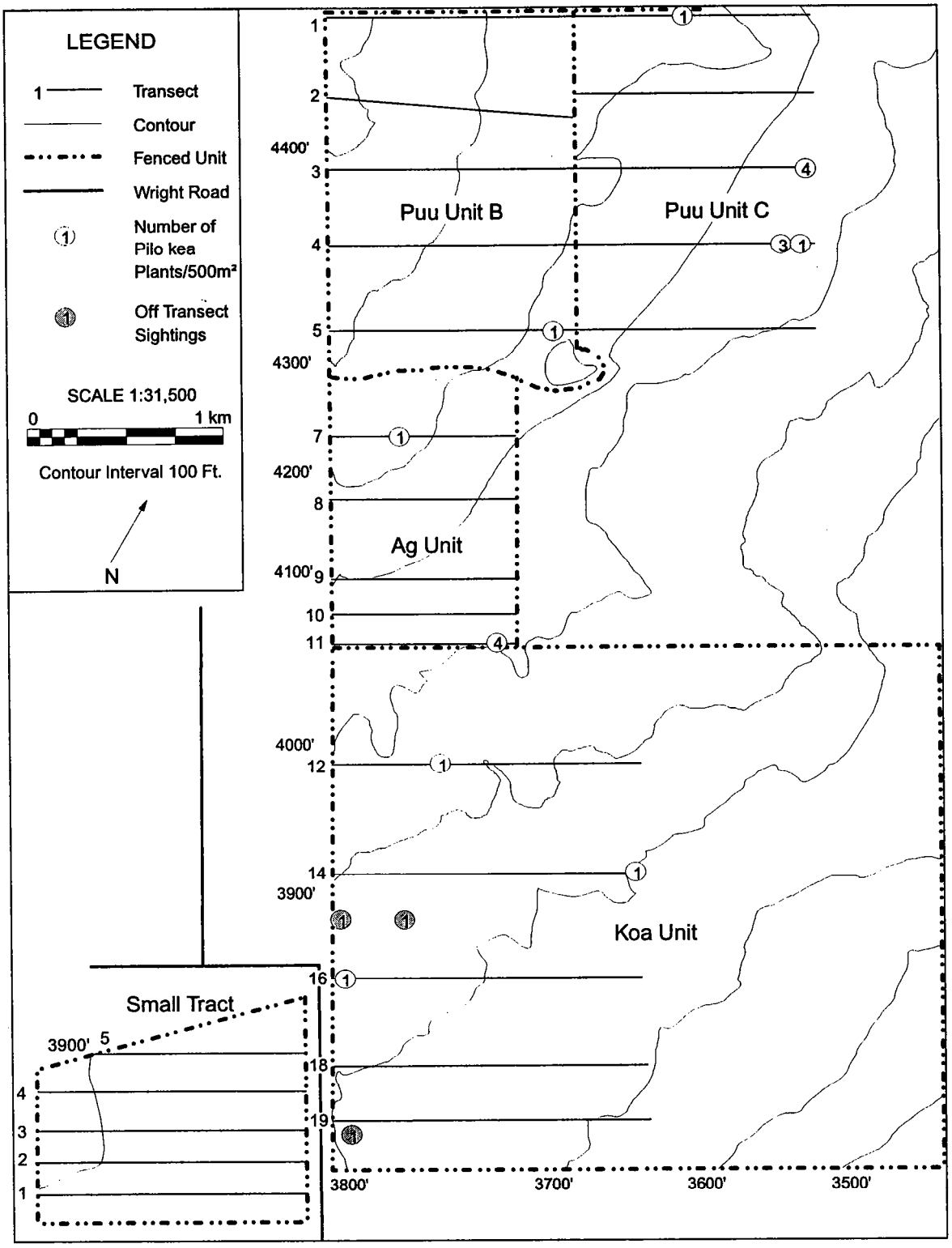

Figure 20. Distribution of pilo kea (*Platydesma spathulata*) along transects in five units of 'Ōla'a Forest, Hawaii Volcanoes National Park.

this loulu (Wagner *et al.* 1990). During the 1992-94 survey, 68 loulu palms were observed along transects in `Ōla`a Forest, and five other palms were noted off-transect (Fig. 21). Most of these palms were in the Small Tract, Ag, or Koa Units; no loulu trees were found along transects inside or outside the Pu`u Unit, although two off-transect sightings were made in this part of the study area. Loulu palms were reproducing in the lower pig-free exclosures of `Ōla`a; in 1992-94, seedlings were observed at three sites in the Small Tract, four sites in the Koa Unit, and at each of three adult palms found in the Ag Unit. Numbers of loulu plants mapped in the Small Tract reflect those found in 1992; seedling numbers increased at two of three Small Tract sites in both 1993 and 1994. Palm fruits are known to be palatable to both feral pigs and alien rats. Seed survival and successful germination in `Ōla`a indicate that removal of one seed predator (pigs) may allow the palm to reproduce even in the presence of other limiting factors; it is unknown whether current levels of reproduction will allow loulu to maintain its population .

Twenty-three years ago, Jacobi and Warshauer (1975) did not find young palms in the western part of `Ōla`a, although they rated the species as rare to uncommon in most of the vegetation types they searched. Less than a decade ago, Anderson *et al.* (1988a) mapped 96 loulu along transects traversing the entire large tract of `Ōla`a Forest. The 1988 survey found loulu in the area now enclosed as the Koa Unit, but most of the palms mapped were in the northeastern quarter of `Ōla`a east of the current study area. This corner of `Ōla`a Forest contains a trench-like geological feature that supports several hundred palms; this concentration of loulu has been repeatedly sighted from the air, but has not been recently visited on the ground. Loulu palms appear to be scattered throughout `Ōla`a below 1,280 m (4,200 ft) elevation, although the reproductive status of the species is not known outside the current study area. This loulu does not naturally occur elsewhere in the Park. At least one species of loulu (possibly *P. lanigera*) has been planted at Volcano House (Fosberg 1966; Morris 1967).

`Ohe mauka (*Tetraplasandra oahuensis*), a tree in the ginseng family (Araliaceae), is a relative of the more common `ōlapa. This species of `ohe mauka occurs on all the main Hawaiian Islands, where it grows in mesic to wet forest (Wagner *et al.* 1990) and in some dry forests (Rock 1974). In the most current treatment of the genus, more than 50 named species and varieties were consolidated into *T. oahuensis* (Wagner *et al.* 1990); the `ohe mauka of `Ōla`a was formerly known as *T. meiandra* var. *rhynchocarpa* (St. John 1984). `Ohe mauka is a small tree with smooth light bark, pinnately compound leaves with shiny leaflets, and large umbellate inflorescences of small pink to yellow-green flowers followed by black to purple fruits. Within `Ōla`a Forest, `ohe mauka was, with one exception, restricted to the Pu`u Unit in the northwestern corner of the surveyed area. Nineteen trees were seen along four Pu`u Unit transects and fence lines, and only one tree was observed near the southern boundary of the Small Tract (Fig. 22). Jacobi and Warshauer (1975) found a similar distribution of `ohe mauka during their survey. They considered the species rare to uncommon in open `ōhi`a forest of the Small Tract and northwestern corner of `Ōla`a, and noted that the tree also occurred in the nearby Cymbidium Acres subdivision and in the

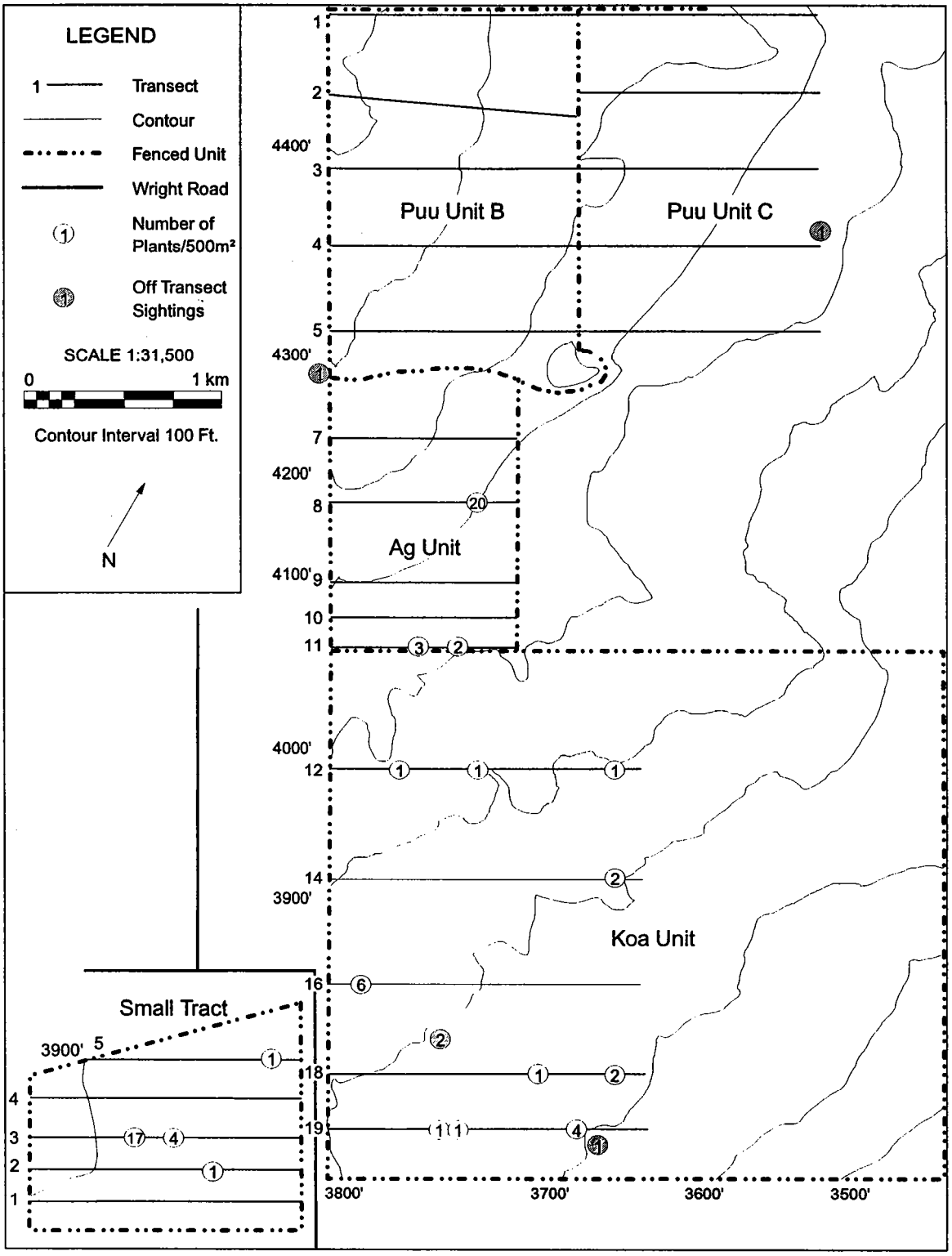

Figure 21. Distribution of loulu (*Pritchardia beccariana*) along transects in five units of ʻŌlaʻa Forest, Hawaii Volcanoes National Park.

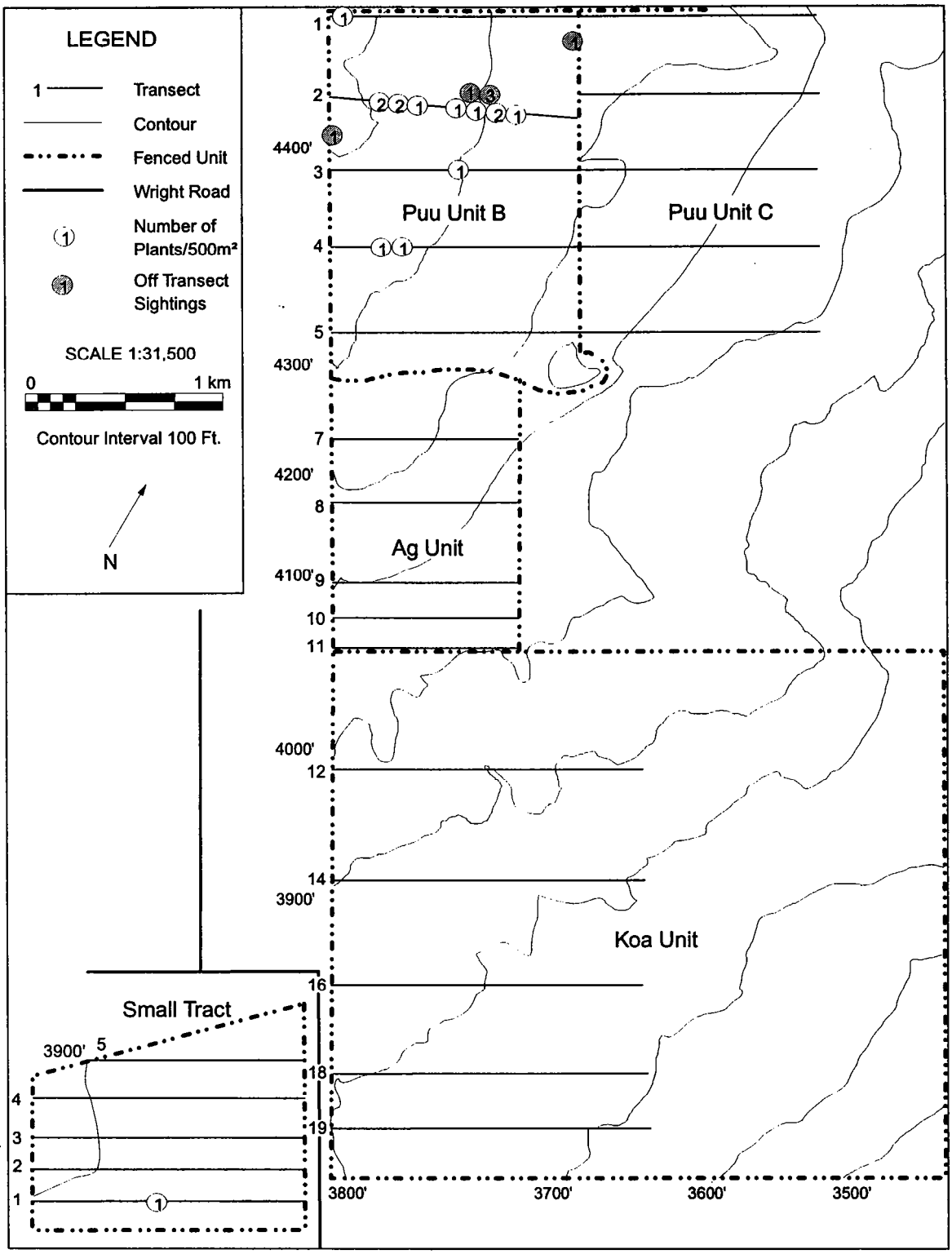

Figure 22. Distribution of 'ohe mauka (*Tetraplasandra oahuensis*) along transects in five units of 'Ōla'a Forest, Hawaii Volcanoes National Park.

adjacent Pu`u Maka`ala NAR, where it persists (The Nature Conservancy 1989). Anderson *et al.* (1988a) did not map `ohe mauka as a rare plant in their `Ōla`a survey. `Ohe mauka does not occur in the Park outside `Ōla`a, although a related species is found in remnant dry forests (Fosberg 1966) and rain forests of Kīlauea's East Rift (Pratt *et al.* 1998).

Olonā (*Touchardia latifolia*) and ōpuhe (*Urera glabra*) are endemic Hawaiian members of the nettle family (Urticaceae). The two are similar in appearance with large, ovate, prominently veined leaves and tight clusters of small unisexual flowers, but olonā is usually a shrub that forms dense stands, while ōpuhe is a single-trunked tree. Both species occur in low to middle-elevation mesic and wet forests on all the main Hawaiian Islands, except Ni`ihau and Kaho`olawe (Wagner *et al.* 1990). Olonā was far more common in `Ōla`a Forest than was ōpuhe in the 1992-94 survey. The total number of olonā plants or clusters of plants was 39 for the entire surveyed area. Half of these were in the small Ag Unit. Nine plants or groups were found in Small Tract, and ten olonā were seen in the much larger Koa Unit (Fig. 23). Only one olonā was encountered outside the Pu`u Unit, and no plants were seen inside the exclosure. A number of the olonā clusters in the study area contained young plants, and many large vigorous stands were observed.

Ōpuhe trees were much less widely distributed in `Ōla`a Forest than were olonā shrubs. Fifteen ōpuhe trees were observed near the eastern and northern edges of the Small Tract; and three trees were found across Wright Road near the western boundary of the Koa Unit (Fig. 23). No ōpuhe trees were noted in the upper part of the study area, although they are likely present as they occur within Pu`u Maka`ala NAR. All but one of the ōpuhe of `Ōla`a were mature trees.

The distribution of olonā has not changed in the 23 years since Jacobi and Warshauer (1975) surveyed the area; they rated the species as occasional in the Small Tract and western part of the Large Tract. As in the current study, Jacobi and Warshauer found ōpuhe to be more uncommon than olonā; they observed both species in the Small Tract and in the areas that later became the Koa and Ag Units. Anderson *et al.* (1988a) encountered only 21 olonā in the areas now enclosed by the Ag and Koa Unit fences; they did not find ōpuhe during their survey. Based on comparisons with these previous surveys, it appears that olonā has increased somewhat in abundance in the last decade, but the ōpuhe population may have declined over the last two decades. Within Hawaii Volcanoes National Park, olonā is restricted to `Ōla`a Forest, but ōpuhe is known from East Rift rain forests and mesic forests of Kīpuka Puaulu (Fosberg 1966) and Kīpuka Kī.

Maua (*Xylosma hawaiiense*) is a tree in the tropical flacourtia family (Flacourtiaceae). Although widely distributed on most of the main Hawaiian Islands, maua is not common in its mesic, wet, and dry forest habitats. More than 80 years ago, Rock (1974) reported maua, which he considered to be two separate species, from a number of localities in which it is no longer present, including Ka`ū sites that supported the largest and best developed trees of the species. Maua was very rare within the `Ōla`a Forest study area; only 11 trees were observed

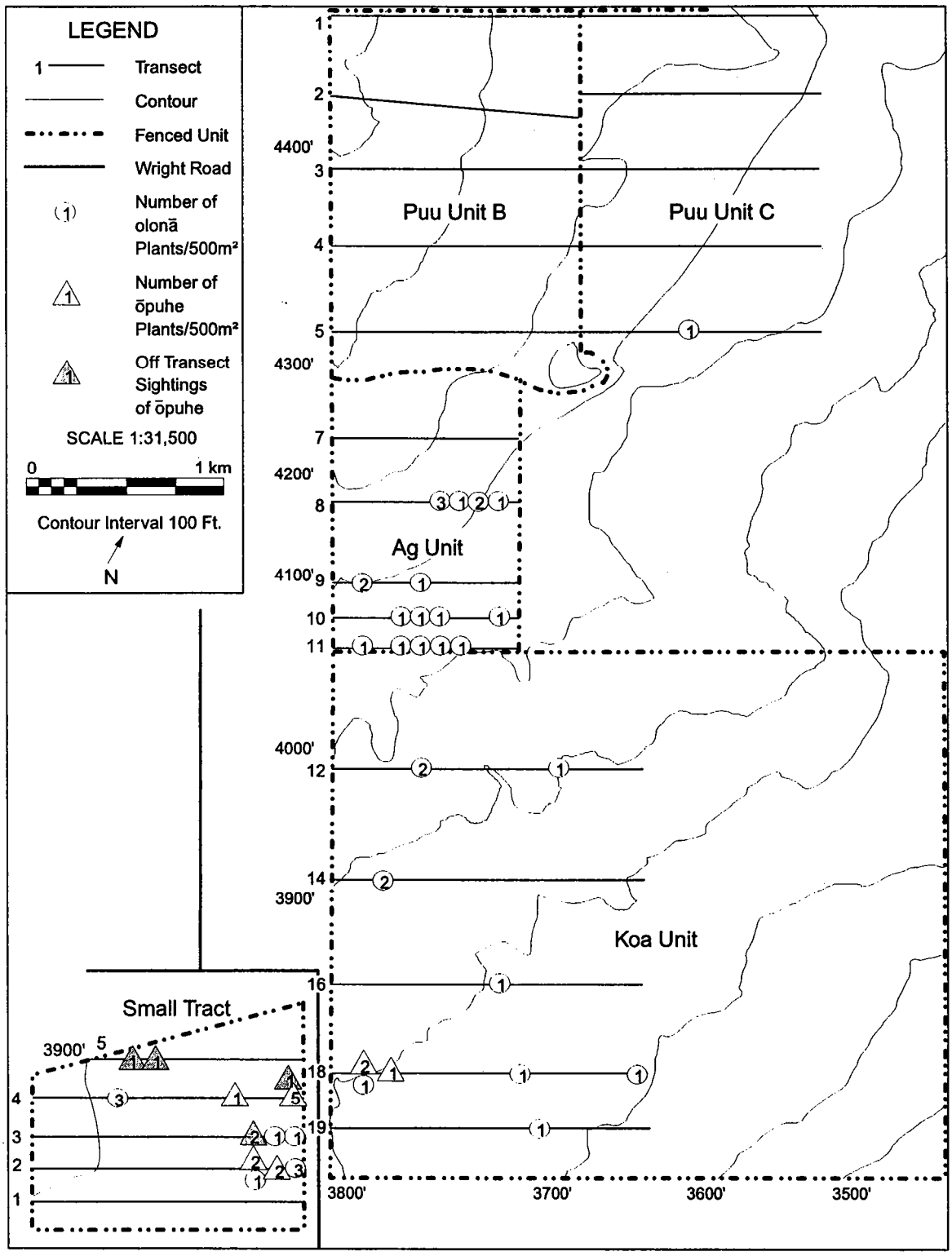

Figure 23 . Distribution of olonā (*Touchardia latifolia*) and ōpuhe (*Urera glabra*) along transects in five units of 'Ōla'a Forest, Hawaii Volcanoes National Park.

at widely separated sites in and outside the Pu`u Unit, in the Koa Unit, and in the Small Tract (Fig. 24). Most of the maua were large, mature trees; some of these exceeded 16 m in height and 0.5 m in diameter. Only one young tree 2 m tall was observed at a site in the Small Tract. Apart from this sapling, maua did not appear to be reproducing in `Ōla`a Forest, although small plants would be very difficult to detect in the dense ground cover. Rats may conceivably be predators of maua fruit; others threats to the species are not known. Maua was also rare in `Ōla`a 23 years ago, when Jacobi and Warshauer (1975) sighted a few trees in what is now the Koa Unit; they did not observe maua in the Small Tract or in the forest now enclosed as the Pu`u Unit. Anderson *et al.* (1988a) noted only four maua trees during their survey of `Ōla`a; these were in the Koa Unit and the area far east of the Pu`u Unit. Outside `Ōla`a rain forests, maua is known in the Park from the mesic forest of Kīpuka Puaulu and dry forests of the lowlands (Fosberg 1966; Abbott and Pratt 1996).

SUMMARY

`Ōla`a Forest is one of the most biologically diverse rain forest areas within Hawaii Volcanoes National Park. Although the study area within `Ōla`a was disturbed by feral pigs in the past and still contains a number of disruptive alien plant species, the fenced units protect habitat that supports or formerly supported a third of the Park's endangered plant species and species of concern, as well as approximately half of the plants considered rare in Hawaii Volcanoes National Park.

No one of the four fenced units and one unfenced area could be singled out as the most important site for rare plants in `Ōla`a Forest, and none of the units contained all of the endangered and rare plant species identified within the study area. While there were clear patterns of distribution across the study area for some of the more frequently encountered rare plants, others were too uncommon or too scattered in distribution to define which units of `Ōla`a represent the most important rare plant habitat.

The Koa Unit and the lower part of the Ag Unit provided preferred habitat for the endangered ha`iwale (*Cyrtandra giffardii*); the Koa Unit was also the presumed site of earlier sightings of the endangered pendent kihi (*Adenophorus periens*) and *Clermontia peleana* and contains all known Park examples of the endangered *Sicyos alba*. The Koa Unit was the locality of most of the recent sightings of the species of concern `akū (*Cyanea tritomantha*) and pōpolo kū mai *(Phytolacca sandwicensis*) and about half of the mōhihi (*Stenogyne scrophularioides*) and *Stenogyne macrantha* found during the survey. Among the rare vines, trees, and shrubs of `Ōla`a, pāwale (*Rumex giganteus*), pāpala (*Charpentiera obovata*), loulu (*Pritchardia beccariana*), and olonā (*Touchardia latifolia*) were particularly frequent in the Koa Unit. Despite the recency of feral pig removal within the Koa Unit, the lobelioids *Clermontia*

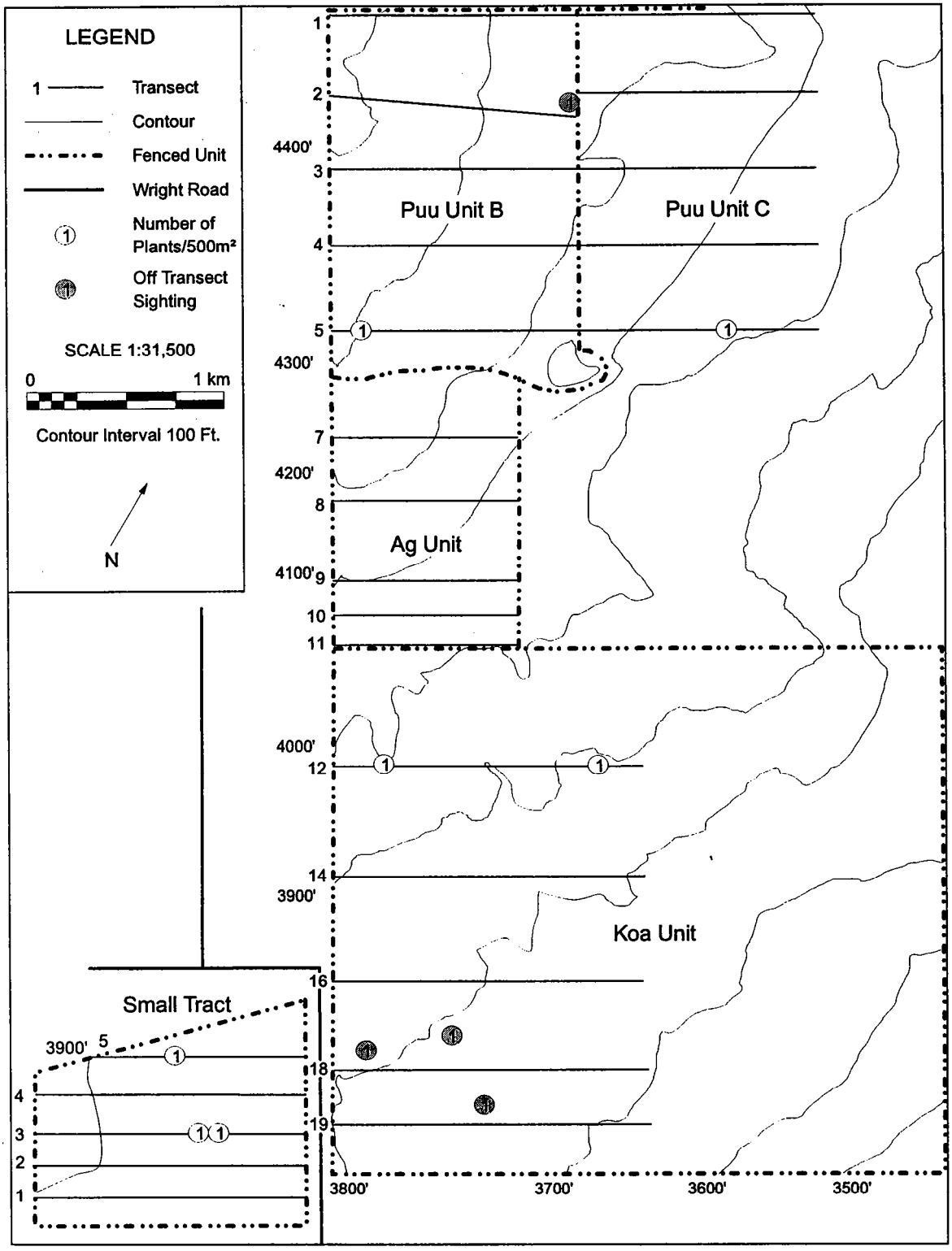

Figure 24. Distribution of maua (*Xylosma hawaiiense*) along transects in five units of ʻŌlaʻa Forest, Hawaii Volcanoes National Park.

parviflora and *C. montis-loa* were numerous in the exclosure. By contrast, two typically terrestrial species of hāhā (*Cyanea pilosa* subsp. *longipedunculata* and *C. degeneriana*) were rare along Koa Unit transects. Only the western half of the Koa Unit was examined during this survey, and the eastern part of the unit containing the koa kīpuka is known to support rare plants, such as koli`i (*Trematolobelia grandifolia*). Rare plant monitoring should be extended to the biologically distinct eastern half of the unit.

Despite its small size, the Ag Unit provided habitat to several of the rarest plants found during this survey, including three species not seen elsewhere in `Ōla`a: *Phyllostegia floribunda, Schiedea diffusa,* and `ōhā kēpau (*Clermontia hawaiiensis*). The unit also contained individuals of other species found to be very rare in `Ōla`a, particularly kilioe (*Embelia pacifica*), `akū (*Cyanea tritomantha*), and pilo kea (*Platydesma spathulata*). The native tree `aiea (*Nothocestrum longifolium*) and the shrubby olonā (*Touchardia latifolia*) were especially numerous within the Ag Unit, as were the terrestrial pala fern (*Marattia douglasii*) and the lobelioid *Cyanea degeneriana.* This unit has a forest canopy that retains many more live `ōhi`a trees than most of the vegetation included in the other units (Jacobi and Warshauer 1975; Jacobi 1983b); the several rare species particularly well represented in the Ag exclosure may be responding positively to the dense shade beneath the tree canopy.

The Pu`u Unit, in the northwestern corner of the Park's `Ōla`a Forest, protects the upper section of the tract; its upper corner elevation is 275 m (900 ft) greater than the lowest reach of the Koa Unit. Despite the intactness of the native forest here and the relative paucity of invasive alien plant species (Pratt and Abbott in prep.), the Pu`u Unit did not contain several of the rare plant species of `Ōla`a and protected only low numbers of other rare plants. A few species, including the lobelioids *Cyanea degeneriana, C. pilosa* subsp. *longipedunculata,* and the candidate endangered koli`i (*Trematolobelia grandifolia*), were frequently seen in this exclosure and were also conspicuous in the unprotected area east of the Pu`u Unit exclosure (Unit C). `Ohe mauka (*Tetraplasandra oahuensis*) trees were scattered throughout the upper Pu`u exclosure; this species was found in none of the other units except the Small Tract, where only one tree was observed.

The area adjacent to the Pu`u Unit, unfenced during the survey but now part of the New Unit, was relatively rich in rare plant species despite the continuing ground disturbance from feral pigs and the greater frequency and abundance of alien plant species (Pratt and Abbott in prep.). In addition to sharing the same lobelioids that occurred within the adjacent exclosure, the unfenced Pu`u Unit C supported most of the *Phyllostegia vestita,* mōhihi (*Stenogyne scrophularioides*), and pilo kea found during this survey of `Ōla`a. These species, at least, appeared to prefer the lower elevations of the New and Koa Units to the seemingly more intact, upper-elevation forests. This area also provided the only sighting of the endemic orchid `awapuhi a Kanaloa (*Liparis hawaiensis*) made in 1992-94, although the orchid has been seen at other `Ōla`a sites in the recent past. The protection of this part of `Ōla`a that began with completion of the New Unit exclosure in 1997 is justified by the many rare plants found during this survey. Fencing and pig removal may arrest further degradation

of native rain forest, and will provide another opportunity to learn more about recovery of native vegetation in disturbed forests.

The Small Tract encloses a relatively small stand of rain forest and has the disadvantage of being exposed to disturbed non-Park lands on three sides. Despite these limitations, the Small Tract today displays some of the most intact and predominantly native rain forest vegetation in the Park. The ground cover of native ferns, herbs, and small shrubs is particularly dense here. Factors contributing to the Small Tract's pronounced recovery are the length of time of protection from feral pigs (nearly 20 years) and the Park's concerted efforts to control the worst invasive alien plant species, such as banana poka *(Passiflora mollissima)*, yellow Himalayan raspberry (*Rubus ellipticus*), and kahili ginger (*Hedychium gardnerianum*). Even with its conspicuous vegetation recovery, the Small Tract did not provide habitat for all or even most of the rare plant species of `Ōla`a. Rare plants particularly well represented in the this unit were pala (*Marattia douglasii*), *Cyanea pilosa* subsp. *longipedunculata*, and opuhē (*Urera glabra*). The Small Tract, along with the western extreme of the Koa Unit, contained stands of pāpala kēpau (*Pisonia brunoniana)* and pāpala (*Charpentiera obovata*) unusual in rain forest and possibly indicative of past mesic conditions. Small Tract also enclosed the best examples of loulu (*Pritchardia beccariana*) seedling reproduction observed within the study area.

Although the 1992-94 survey results reported here did not include information on the eastern half of the Park's `Ōla`a Forest, a previous, more extensive survey of weeds throughout `Ōla`a (Anderson *et al.* 1988a) did contain data on the distribution of rare plants in this distant part of the tract. Maps of rare to uncommon species from the 1988 survey indicated that only the upper northeastern portion of the eastern third of the tract provided habitat for rare plants, including low numbers of `aiea, `āku, the orchid `awapuhi o Kanaloa, and hāhā (*Cyanea pilosa*), as well as a dense concentration of loulu palms. The eastern third of the large tract of `Ōla`a was found to be heavily invaded by palmgrass (*Setaria palmifolia*); because of dense palmgrass and other weeds, few significant rare plant resources are thought to be in the southeastern reaches of `Ōla`a Tract.

Before the 1997 enclosure of the New Unit, the forest immediately east of the Pu`u Unit called the Pu`u Unit C in this report, was the most outstanding candidate area for fencing and protection. Pig removal in this area will protect at least two rare mint species only infrequently found elsewhere in `Ōla`a and will greatly strengthen the protection afforded to the lobelioids koli`i (*Trematolobelia grandifolia*) and *Cyanea pilosa* subsp. *longipedunculata*. As the "Unit C" area was already partially fenced by other units on three sites, a minimal amount of fencing was required to enclose an area of perhaps 800 ha (2,000 a). Since this area has been enclosed, only the far northeastern corner of the tract remains to be more intensively examined for additional populations of rare plants. Even though this northeastern section of `Ōla`a has a greater cover of weeds than the western section of the tract, it contains unusual geological features of a trench and craters that may support

populations of rare plant species, including some possibly not protected within the current system of exclosures. This corner of `Ōla`a, although remote, deserves further scrutiny.

The four `Ōla`a Forest exclosures, as well as the newly fenced New Unit outside the Pu`u Unit, are examples of the ecosystem management approach to protecting important resources in Hawaii Volcanoes National Park. Such an approach has been used for more than a decade in the Park and has been particularly effective in managing areas with moderate infestations of alien plants (Tunison and Stone 1992). In `Ōla`a Forest, the ecosystem management approach has been to fence units as large as possible, remove feral pigs, and initiate alien plant control where feasible. Areas with the most intact forest and fewest invasive alien plants were fenced first. The presence of rare plants was a factor in site selection, but the survey that provided rare plant data for the selection process was not intensive enough to identify all important rare plant concentrations; the survey goal was to provide a rapid and extensive sampling of alien plants and rare species across the entire `Ōla`a Tract (Anderson *et al.* 1988a).

The ecosystem approach has clearly been effective in preventing further forest degradation and in promoting recovery of native forest vegetation. It is not, however, a perfect means to protect the rare plant resources of the National Park. While protection of the most intact forest is more likely to result in rapid vegetation recovery, it does not necessarily ensure protection of the rarest plants. Some of the rare and endangered plants of `Ōla`a are currently growing in disturbed areas for reasons not well understood; such unlikely sites may fulfill important habitat requirements of rare plants or may simply result from chance. Nonetheless, based on the findings of the current and previous rare plant surveys, the incremental addition of fenced units in `Ōla`a has resulted in the protection of sizable populations of the known rare plants of the region. In the future, a combination of effective large-scale ecosystem management and efforts specifically directed toward rare plants may be required to ensure the long-term survival of some rare species within the Park.

CONSIDERATIONS FOR MANAGEMENT OF `ŌLA`A RARE PLANTS

1) Removal of feral pigs from the newly fenced area east of the Pu`u Unit (New Unit) should be a Park priority. Feral pig populations here continue to degrade the native forest and encourage the expansion of alien plants (Pratt and Abbott in prep.).

2) The focus of alien plant control efforts on the Pu`u Unit and the Ag Unit would be appropriate and in keeping with the Park's approach to managing Special Ecological Areas (Tunison and Stone 1992). Both are relatively small, contain significant rare plant resources, have manageable levels of alien plants, and are adjacent to larger areas in Pu`u Maka`ala NAR with few weed problems. Continued expansion of alien plant control in the Koa Unit to the east of the currently managed western strip near Wright Road is also warranted.

3) It is important to continue remonitoring vegetation plots in the Koa Unit that were established in 1991 to follow recovery after feral pig removal. While the original data set indicated the presence of a large number of alien plants (Tunison *et al.* in prep.), the prevalence of alien plants may decrease with time. An eventual decrease of aliens would be an indication of likely successful recovery in other fenced units.

4) Expansion of rare plant searches and monitoring to the eastern half of the Koa Unit and that part of the New Unit not surveyed by the current study would fill in the gap of knowledge about rare plants in these now managed sections of `Ōla`a Forest.

5) Intensive monitoring of some of the rare plant populations of `Ōla`a to evaluate stand structure and reproduction would provide managers with important information. Some species may be adequately reproducing and require no further assistance. Others may require human intervention to persist with viable populations within the Park. If some rare plant species appear to be inadequately reproducing and are in danger of being lost from the Park, a small-scale propagation program could be developed to grow selected rare plant species in the Park greenhouse for outplanting in one or more of the protected `Ōla`a exclosures.

6) The impacts of rats and alien invertebrates on the reproduction of selected rare plants of `Ōla`a should be evaluated. Species likely harmed by rats include *Cyanea* spp., koli`i (*Trematolobelia grandifolia*), loulu (*Pritchardia beccariana*), the endangered `ānunu (*Sicyos alba*), and native mints (*Phyllostegia* spp.).

LITERATURE CITED

Abbott, L. L. And L. W. Pratt. 1996. *Rare plants of Nāulu Forest and Poliokeawe Pali, Hawaii Volcanoes National Park.* Cooperative National Park Resources Studies Unit Technical Report 108. Department of Botany, University of Hawaii, Honolulu.

Anderson, S. J. and P. K. Higashino. 1985-87. Vegetation plots and transects inside and outside the `Ōla`a Forest Pu`u Unit. Unpublished data, Biological Resources Division-U. S. Geological Survey , Hawaii Volcanoes National Park.

Anderson, S. J., P. K. Higashino, J. T. Tunison, and L. W. Cuddihy. 1988a. Botanical survey of the `Ōla`a Forest, Large Tract. Unpublished data, Biological Resources Division-U. S. Geological Survey, Hawaii Volcanoes National Park.

Anderson, S. J., J. T. Tunison, and L. W. Cuddihy. 1988b. Botanical survey of Kīlauea East Rift rain forests. Unpublished data, Biological Resources Division-U. S. Geological Survey, Hawaii Volcanoes National Park.

Baker, J. K. 1979. The feral pig in Hawaii Volcanoes National Park. Pp. 365-367 In R. M. Linn (ed.) *Proceedings of the First Conference on Scientific Research in the National Parks, New Orleans.* U. S. National Park Service Transactions and Proceedings Series 5.

Beccari, O. and J. F. Rock. 1921. A monographic study of the genus *Pritchardia. Memoirs of the Bernice P. Bishop Museum* 8(1): 1-77.

Belfield, T. R. 1998. *Botanical survey of Kīlauea Volcano East Rift craters, Hawaii Volcanoes National Park.* Cooperative National Park Resources Studies Unit Technical Report 114, Department of Botany, University of Hawaii, Honolulu.

Bishop, L. E. 1974. Revision of the genus *Adenophorus* (Grammitidaceae). *Brittonia* 26: 217-240.

Burton, P. J. 1980. *Light regimes and Metrosideros regeneration in a Hawaiian montane rain forest.* M. S. Thesis, Department of Botany, University of Hawaii, Honolulu. 378 pp.

Char, W. P. and C. H. Lamoureux. 1985. Puna geothermal area biotic assessment, Puna District, County of Hawaii. Final Report. A report prepared for the Hawaii State Department of Planning and Economic Development by the Department of Botany, University of Hawaii at Manoa, Honolulu. 127 pp. & appendices.

Clarke, G. G., L. W. Cuddihy, J. A. Davis, and S. J. Anderson. 1982. A botanical survey of Keauhou Ranch and Kīlauea Forest, Hawaii; with emphasis on the endangered plant species *Vicia menziesii* Spreng. Unpublished report, Endangered Plant Species Program, Division of Forestry and Wildlife, Department of Land and Natural Resources, Hilo, Hawaii. 220 pp.

Cuddihy, L. W., S. J. Anderson, C. P. Stone, and C. W. Smith. 1986. *A botanical baseline study of forests along the East Rift of Hawaii Volcanoes National Park adjacent to Kahauale`a.* Cooperative National Park Resources Studies Unit Technical Report 61, Department of Botany, University of Hawaii, Honolulu. 180 pp.

Cuddihy, L. W., J. A. Davis, and S. J. Anderson. 1982. A botanical survey of the proposed Laupāhoehoe Natural Area Reserve, Hawaii. Unpublished report, Endangered Plant Species Program, Division of Forest and Wildlife, Department of Land and Natural Resources, Hilo, Hawaii. 65 pp.

Cuddihy, L. W. 1985. Special Ecological Area -`Ōla`a Small Tract, action plan and vascular plant checklist. Unpublished report, Resources Management Division, Hawaii Volcanoes National Park.

Degener, O. 1946. *Flora Hawaiiensis or new illustrated flora of the Hawaiian Islands,* Books 1-4. Privately published.

Degener, O. and I. Degener. 1960. *Flora Hawaiiensis or new illustrated flora of the Hawaiian Islands,* Book 6. Privately published.

Degener, O. and I. Degener. 1971. *Rumex* of Hawaii. *Phytologia* 21(3): 139-145.

Doty, M. S. and D. Mueller-Dombois. 1966. *Atlas for bioecology studies in Hawaiian Volcanoes National Park.* Hawaii Botanical Science Paper No. 2. Department of Botany, University of Hawaii, Honolulu. 507 pp.

Fagerlund, G. O. and A. L. Mitchell. 1944. A checklist of the plants of Hawaii National Park, Kīlauea-Mauna Loa section, with a discussion of the vegetation. *Natural History Bulletin* 9, Hawaii National Park. 65 pp.

Foote, D., K. Magnacca, and E. Richards. In prep. Changes in community structure of *Drosophila* and their host plants across disturbance thresholds in wet forests of Hawaii Volcanoes National park.

Fosberg, F. R. 1966. Vascular plants. Pp 153-238 In M. S. Doty and D. Mueller-Dombois (eds.). *Atlas for bioecology studies in Hawaiian Volcanoes National Park.* Hawaii Botanical Science Paper No. 2. Department of Botany, University of Hawaii, Honolulu.

Fosberg, F. R. 1969. Miscellaneous notes on Hawaiian plants - 5. *Occasional Paper of Bernice P. Bishop Museum* 24(2): 9-24.

Fosberg, F. R. 1975. *Revised check-list of vascular plants of Hawaii Volcanoes National Park.* Cooperative National Park Resources Studies Unit Technical Report No. 5, Department of Botany, University of Hawaii, Honolulu. 19 pp.

Fosberg, F. R. and D. Herbst. 1975. Rare and endangered species of Hawaiian vascular plants. *Allertonia* 1(1): 1-72.

Gerrish, G. 1980. Photometric monitoring of foliage loss from a wind storm, island of Hawai`i. Pp. 129-135 In C. W. Smith (ed.) *Proceedings Third Conference in Natural Sciences, Hawaii Volcanoes National Park,* June 4-6, 1980.

Giambelluca, T. W., M. A. Nullet, and T. A. Schroeder. 1986. *Rainfall atlas of Hawai`i.* Report R76. Water Resources Research Center with the cooperation of Department of Meteorology, University of Hawaii. State of Hawaii, Department of Land and Natural Resources, Division of Water and Land Development. Honolulu. 267 pp.

Hawaii Department of Land and Natural Resources. 1970. *An inventory of basic water resources data: island of Hawaii.* Report R34. State of Hawaii, Dept. of Land and Natural Resources, Division of Water and Land Development. Honolulu. 188 pp.

Herat, T. K. and R. M. Herat. 1975. *A checklist and status report of the ferns and fern allies in Hawaii Volcanoes National Park.* Cooperative National Park Resources Studies Unit Technical Report No. 8, Department of Botany, University of Hawaii, Honolulu. 58 pp.

Hillebrand, W. F. 1981. *Flora of the Hawaiian Islands, a description of their phanerogams and vascular cryptogams.* Lubrecht & Cramer, Monticello, New York. 673 pp. [Facsimile of the edition of 1888.]

Holcomb, R. T. 1987. Eruptive history and long-term behavior of Kīlauea Volcano. Chapter 12, pp. 261-350 In R. W. Decker, T. L. Wright, and P. H. Stauffer. *Volcanism in Hawaii*, vol. 1. U. S. Geological Survey Professional Paper 1350. U. S. Government Printing Office, Washington, D. C.

Jacobi, J. D. 1980a. Vegetation map overlay, Kūlani, Hawaii. Hawaii Forest Bird Survey, U. S. Fish and Wildlife Service and `Ōhi`a Forest Study, University of Hawaii. Unpublished map, in files of Biological Resources Divsion-U. S. Geological Survey, Kilauea Field Station, Hawaii Volcanoes National Park.

Jacobi, J. D. 1980b. Vegetation map overlay, Volcano, Hawaii. Hawaii Forest Bird Survey, U. S. Fish and Wildlife Service and `Ōhi`a Forest Study, University of Hawaii. Unpublished map, in files of Biological Resources Divsion-U. S. Geological Survey, Kilauea Field Station, Hawaii Volcanoes National Park.

Jacobi, J. D. 1983a. *Metrosideros* dieback in Hawaii: a comparison of adjacent dieback and non-dieback rain forest stands. *New Zealand Journal of Ecology* 6: 79-97.

Jacobi, J. D. 1983b. Vegetation map overlay, Kīlauea Crater, Hawaii. Hawaii Forest Bird Survey, U. S. Fish and Wildlife Service. Unpublished map, in files of Biological Resources Divsion-U. S. Geological Survey, Kilauea Field Station, Hawaii Volcanoes National Park.

Jacobi, J. D. and F. R. Warshauer. 1975. A preliminary bioecological survey of the `Ōla`a Tract, Hawaii Volcanoes National Park. Prepared for the Hawaii Natural History Association, Hawaii Volcanoes National Park. Unpublished report, Library, Hawaii Volcanoes National Park.

Jacobi, J. D., G. Gerrish, and D. Mueller-Dombois. 1983. `Ōhi`a dieback in Hawai`i: vegetation changes in permanent plots. *Pacific Science* 37(4): 327-337.

Lammers, T. G. 1991. Systematics of *Clermontia* (Campanulaceae-Lobelioideae). *Systematic Botany Monographs*, Vol. 32. The American Society of Plant Taxonomists, Ann Arbor, Michigan. 97 pp.

Lamoureux, C. H. 1976. Endangered plants in Hawaii Volcanoes National Park. Pp 123-125 In C. W. Smith (ed.) *Proceedings of the First Conference in Natural Sciences in Hawaii, Hawaii Volcanoes National Park.*

Lockwood, J. P. and P. W. Lipman. 1987. Holocene eruptive history of Mauna Loa volcano. Chapter 18, pp. 509-535 In R. W. Decker, T. L. Wright, and P. H. Stauffer. *Volcanism in Hawaii*, vol. 1. U. S. Geological Survey Professional Paper 1350. U. S. Government Printing Office, Washington, D. C.

Lockwood, J. P and F. Trusdell. In prep. Geology map of the northeast rift, Mauna Loa, Hawai`i. Sheet 1

MacDonald, G. A., A. T. Abbott, and F. L. Peterson. 1983. *Volcanoes in the Sea; the geology of Hawaii.* 2nd edition. University of Hawaii Press, Honolulu. 517 pp.

Morris, D. K. 1967. The history of native plant propagation and re-introduction in Hawaii Volcanoes National Park. Unpublished report, Library, Hawaii Volcanoes National Park.

Mueller-Dombois, D., with J. D. Jacobi, R. G. Cooray, and N. Balakrishnan. 1977. *`Ōhi`a rain forest study: ecological investigations of the `ōhi`a dieback problem in Hawai`i.* Cooperative National Park Resources Studies Unit Technical Report 20, Department of Botany, University of Hawaii, Honolulu. 102 pp. & maps.

Mueller-Dombois, D., with J. D. Jacobi, R. G. Cooray, and N. Balakrishnan. 1980. *`Ōhi`a rain forest study: ecological investigations of the `ōhi`a dieback problem in Hawai`i.* College of Tropical Agriculture and Human Resources, Hawaii Agricultural Experiment Station Miscellaneous Publication 183. 64 pp.

National Park Service. 1973. Draft environmental statement, natural resources management plan, Hawaii Volcanoes National Park. Unpublished report, Library, Hawaii Volcanoes National Park. 69 pp.

National Park Service. 1985. Draft land protection plan, Hawaii Volcanoes National Park. Unpublished report, Library, Hawaii Volcanoes National Park. 40 pp. & appendices.

National Park Service. 1996. Resources Management Plan, Hawaii Volcanoes National Park, revised February 15, 1996. Unpublished plan, Resources Management Division, Hawaii Volcanoes National Park. 171 pp. & appendices.

Pratt, L. W. and L. L. Abbott. In prep. Vegetation inside and outside a feral pig exclosure in `Ōla`a Forest, Hawaii Volcanoes National Park. Cooperative National Park Resources Studies Unit Technical Report, Department of Botany, University of Hawaii, Honolulu.

Pratt, L. W., L. L. Abbott, and D. K. Palumbo. 1998. *Vegetation above a feral pig barrier fence in rain forests of the East Rift, Hawaii Volcanoes National Park.* Cooperative National Park Resources Studies Unit Technical Report 116, Department of Botany, University of Hawaii, Honolulu.

Pratt, L. W., L. L. Abbott, D. K. Palumbo, and T. R. Belfield. In prep. Rare plants of Kīpuka Puaulu, Hawaii Volcanoes National Park. Cooperative National Park Resources Studies Unit Technical Report, Department of Botany, University of Hawaii, Honolulu.

Robinson, W. J. 1912. A taxonomic study of the Pteridophyta of the Hawaiian Islands - III. *Bulletin of the Torrey Botanical Club* 39(5): 227-248 & plates.

Robinson, W. J. 1913. A taxonomic study of the Pteridophyta of the Hawaiian Islands - III. *Bulletin of the Torrey Botanical Club* 40(5): 193-228 & plates.

Rock, J. F. 1919a. Cyrtandreae Hawaiienses, section Microcalyces Hillebr. *American Journal of Botany* 6: 203-216.

Rock J. F. 1919b. A monographic study of the Hawaiian species of the tribe Lobelioideae family Campanulaceae. *Memoirs of Bernice P. Bishop Museum.* Vol VII., No. 2. Bishop Museum Press, Honolulu. 394 pp.

Rock, J. F. 1957. Some new Hawaiian lobelioids. *Occasional Papers of Bernice P. Bishop Museum* 22(5): 35-66.

Rock, J. F. 1962. Hawaiian lobelioids. *Occasional Papers of Bernice P. Bishop Museum* 23(5): 65-75.

Rock, J. F. 1974. *The indigenous trees of the Hawaiian Islands.* Pacific Tropical Botanical Garden Lawai, Kauai, Hawaii and Charles E. Tuttle Company, Rutland, Vermont. 548 pp. [Reprint of 1913 edition published under patronage].

Sarr, Z., N. Shema, M. Morin, and C. Stone. In prep. Distribution and status of forest bird populations within Hawaii Volcanoes National Park during 1992-94. Cooperative National Park Resources Studies Unit Technical Report. Department of Botany, University of Hawaii, Honolulu.

Sato, H. H., W. Ikeda, R. Paeth, R. Smythe, and M. Takehiro, Jr. 1973. *Soil survey of the island of Hawaii, State of Hawaii.* U. S. Dept. of Agriculture, Soil Conservation Service, in cooperation with the University of Hawaii Agricultural Experiment Station. 115 pp. & maps.

Sherff, E. E. 1935. Revision of *Haplostachys, Phyllostegia,* and *Stenogyne. Bernice P. Bishop Museum Bulletin* 136, Honolulu. 101 pp.

Sohmer, S. H. 1972. Revision of the genus *Charpentiera* (Amaranthaceae). *Brittonia* 24: 283-312.

St. John, H. 1936. A revision of the Hawaiian species of *Labordia* described by H. Baillon. Hawaiian plant studies 4. *Occasional Papers Bernice P. Bishop Museum* 15(2): 21-35.

St. John, H. 1973. *List and summary of the flowering plants of the Hawaiian Islands.* Pacific Tropical Botanical Garden Memoir No. 1. Lawai, Kauai, Hawaii. 519 pp.

St. John, H. 1976. New species of Hawaiian plants collected by David Nelson in 1779. Hawaiian Plant Studies 52. *Pacific Science* 30(1): 7-44.

St. John, H. 1978. The Cucurbitaceae of Hawaii, I. Generic revision. Hawaiian Plant Studies 67. *Bot. Jahrb. Syst.* 99(4): 490-497.

St. John, H. 1982. Monograph of *Trematolobelia* (Lobeliaceae). Hawaiian Plant Studies 107. *Pacific Science* 36 (4): 483-506.

St. John, H. 1984. Novelties among the Phanerogamae. Hawaiian Plant Studies 123. *Bulletin of the Torrey Botanical Club* 111(4): 479-482.

Stone, B. C. 1962. A monograph of the genus *Platydesma* (Rutaceae). *Journal of the Arnold Arboretum* 43(4): 410-427.

Stone, C. P. 1985. Alien animals in Hawai`i's native ecosystems: toward controlling the adverse effects of introduced vertebrates. Pp. 251-297 In C. P. Stone and J. M Scott (eds.) *Hawai`i's terrestrial ecosystems; preservation and management.* University of Hawaii Cooperative National Park Resources Studies Unit. University of Hawaii Press, Honolulu.

Stormont, W. T. 1998. Draft environmental assessment for fence construction, Anunu Unit, Pu`u Maka`ala Natural Area Reserve. Proposed by Natural Area Reserve Program, Division of Forestry and Wildlife, Hawaii Branch, Department of Land and Natural Resources. December, 1998. 11 pp. & appendices.

Swezy, O. H. 1954. *Forest entomology in Hawaii.* Bernice P. Bishop Museum Special Publication 44. Published in collaboration with the Hawaiian Botanical Society and the Hawaiian Entomological Society. Honolulu. 266 pp.

The Nature Conservancy of Hawaii, Hawaii Heritage Program. 1989. Pu`u Maka`ala area plant species checklist. Appendix 3 of Pu`u Maka`ala Natural Area Reserve Resource Information Notebook 1. 6 pp.

Tunison, J. T., C. P. Stone, and L. W. Cuddihy. 1986. SEAs provide ecosystem focus for management and research. *Park Science* 6(3): 10-12.

Tunison, J. T. and C. P. Stone. 1992. Special ecological areas: an approach to alien plant control in Hawaii Volcanoes National Park. Pp. 781-798 In C. P. Stone, C. W. Smith, and J. T. Tunison (eds.). *Alien plant invasions in native ecosystems of Hawai`i: management and research.* University of Hawaii Cooperative National Park Resources Studies Unit. University of Hawaii Press, Honolulu.

Tunison, J. T., J. Leialoha, and R. Loh. In prep. Vegetaion recovery two years after pig removal in a tree fern rain forest, Hawaii Volcanoes National Park. Cooperative National Park Resources Studies Unit Technical Report. Department of Botany, University of Hawaii, Honolulu.

U. S. Fish and Wildlife Service, Department of the Interior. 1976. Endangered and threatened wildlife and plants; proposed endangered status for some 1700 U. S. vascular plant taxa. June 16, 1976. *Federal Register* 41(117): 24524-24572.

U. S. Fish and Wildlife Service, Department of the Interior. 1980. Endangered and threatened wildlife and plants; review of plant taxa for listing as endangered or threatened species. December 15, 1980. *Federal Register* 45(242): 82480-82569.

U. S. Fish and Wildlife Service, Department of the Interior. 1990. Endangered and threatened wildlife and plants; review of plant taxa for listing as endangered or threatened species; notice of review. February 21, 1990. *Federal Register* 55(35): 6184-6229.

U. S. Fish and Wildlife Service, Department of the Interior. 1994a. Endangered and threatened wildlife and plants; determination of endangered or threatened status for 21 plants from the island of Hawaii, State of Hawaii. *Federal Register* 59(43): 10305-10325.

U. S. Fish and Wildlife Service, Department of the Interior. 1994b. Endangered and threatened wildlife and plants; endangered status for 12 plants from the Hawaiian Islands. *Federal Register* 59(217: 56333-56351.

U. S. Fish and Wildlife Service, Department of the Interior. 1995. Endangered and Threatened wildlife and plants; proposed endangered status for thirteen plants from the island of Hawaii, State of Hawaii. *Federal Register* 60(185): 49377-49392.

U. S. Fish and Wildlife Service, Department of the Interior. 1996a. Recovery plan for the Big Island plant cluster. U. S. Fish and Wildlife Service, Portland, Oregon. 202+ pp.

U. S. Fish and Wildlife Service, Department of the Interior. 1996b. Endangered and threatened wildlife and plants; determination of endangered status for thirteen plants from the island of Hawaii, State of Hawaii. *Federal Register* 61(198): 53137-53152.

U. S. Fish and Wildlife Service, Department of the Interior. 1997. Plants of the Hawaiian Islands, Species of concern. Updated September 26, 1997. List distributed by U. S. Fish and Wildlife Service, Pacific Islands Ecoregion, Ecological Services, Honolulu.

Wagner, W. H. Jr. 1995. Evolution of Hawaiian ferns and fern allies in relation to their conservation status. *Pacific Science* 49(1): 31-41.

Wagner, W. H. Jr. and F. S. Wagner. 1992. Pteridophytes of Hawaii, Identification Key. Preliminary key designed as part of a forthcoming manual of the ferns of Hawaii. Ann Arbor, Michigan and Honolulu, Hawaii. Unpublished, provided by the authors. 40 pp.

Wagner, W. H. Jr. and F. S. Wagner. 1995. Revised tentative checklist of Hawaiian Pteridophytes, February 22, 1995. Unpublished, provided by the authors. 10 pp.

Wagner, W. L., D. R. Herbst, and S. H. Sohmer. 1990. *Manual of the flowering plants of Hawai`i.* Bishop Museum Special Publication 83. University of Hawai`i Press and Bishop Museum Press, Honolulu. 1854 pp.

Wright, R. A. And D. Mueller-Dombois. 1988. Relationships among shrub population structure, species associations, seedling root form and early volcanic succession, Hawaii. Pp. 87-104 In M. J. A. Werger, P. J. M. van der Aart, H. J. During, and J. T. A. Verhoeven (eds.). *Plant form and vegetation structure.* SPB Academic Publishing, The Hague, The Netherlands.

Zimmer, N. G. 1982. Rare plant packet on *Charpentiera obovata.* Unpublished report in files of Resources Management Division, Hawaii Volcanoes National Park. 2 pp & maps.

APPENDIX 1
COLLECTIONS OF RARE PLANTS FROM `ŌLA`A FOREST IN THE HAWAII VOLCANOES NATIONAL PARK HERBARIUM

* Specimens collected at sites adjacent to `Ōla`a Forest

Adenophorus periens L. E. Bishop, None from `Ōla`a

Anoectochilus sandvicensis Lindl.
Collector/No.: Andy Kikuta, sn Date: Sept. 14, 1990
Locality: HAVO, `Ōla`a Tract, Transect 19, ca. 1,000 m from fence, elevation ca. 3,800 ft.

*Asplenium schizophyllum?*C. Chr.
Collector/No.: L. W. Cuddihy, 1860 Date: Dec. 5, 1984
Locality: HAVO, `Ōla`a tract, elevation ca. 4,000 ft.

Charpentiera obovata Gaud.
Collector/No.: Bill Mull, sn Date: July 14, 1997
Locality: `Ōla`a Forest, Koa Unit, Transect 18, 505 m, elevation ca. 3,800 ft.

Collector/No.: L. W. Pratt 2944; 2945 Date: June 5, 1996
Locality: `Ōla`a Forest, Koa Unit, Transect 18, elevation ca. 3,750 ft

Clermontia hawaiiensis (Hillebr.) Rock
*Collector/No.: Don Drake, 96 (2 sheets) Date: July 8, 1991
Locality: Wright Road, UH Experimental Farm (adjacent to `Ōla`a Tract)

Clermontia montis-loa Rock
Collector/No.: L. W. Cuddihy, 1950 Date: June 20, 1985
Locality: `Ōla`a Tract Pu`u Unit, Transect 2B

Collector/No.: L. Katahira, sn Date: May 2, 1985
Locality: `Ōla`a Tract

*Collector/No.: T. Herat, R. Herat, & P. Higashino, 573/574/574
Date: June 15, 1974
Locality: `Ōla`a Forest Reserve, ca. 10.8 km from junction of Stainback Highway and Highway 17

*Collector/No.: Tim Tunison, 1985-35 Date: May 2, 1985
Locality: Pu`u Maka`ala area, at edge of Disappointment Road, 0.5 m from Stainback Highway

APPENDIX 1 (Continued)

Clermontia parviflora Gaud. ex A. Gray

Collector/No.: L. W. Cuddihy, 1886 Date: April 25, 1985
Locality: `Ōla`a Small Tract

Collector/No.: L. W. Cuddihy, 1937 Date: June 5, 1985
Locality: `Ōla`a Large Tract, Pu`u Unit, Transect 4B

Collector/No.: L. W. Cuddihy, 2436 Date: Sept. 4, 1991
Locality: HAVO, `Ōla`a Forest, elevation ca. 4,200 between Pu`u and Ag Units

*Collector/No.: G. E. Olson, sn (Cat. #1101)Date: February 6, 1939
Locality: Along road at start of Kulani trail

*Collector/No.: T. Herat, R. Herat, & P. Higashino, 602
Date: June 15, 1974
Locality: `Ōla`a Forest Reserve, ca. 9.6 mi from the junction of Stainback Highway and Highway 17 toward Kulani Prison at ca. 1070 m along jeeptrack

*Collector/No.: T. Herat, R. Herat, & P. Higashino, 929
Date: July 6, 1974
Locality: `Ōla`a Forest Reserve, ca. 9.6 mi from the junction of Stainback Highway and Highway 17 toward Kulani Prison at ca. 870 m.

Clermontia peleana Rock, None in HAVO Herbarium.

Fosberg 1966 lists Mueller-Dombois H-166 from "Kilauea in tall *Metrosideros* forest." This specimen may be at the University of Hawaii/Manoa Botany Department Herbarium.

Cyanea degeneriana F. Wimmer

Collector/No.: L. W. Cuddihy, 1857 Date: Dec. 5, 1984
Locality: `Ōla`a Tract, elevation ca. 4,000 ft.

*Collector/No.: G. E. Olson, sn (Cat. 1102) Date.: Feb. 6, 1939
Locality: ½ mile Kulani Trail
Note: Original label identification *Cyanea pilosa* var.*glabrifolia*

Cyanea pilosa A. Gray subsp. *longipedunculata* (Rock) Lammers

Collector/No.: Gar Clarke, 9 Date: July 30, 1976
Locality: `Ōla`a Tract, 3800 ft elevation

APPENDIX 1 (Continued)

Cyanea pilosa A. Gray subsp. *longipedunculata* (Rock) Lammers (Continued)
Collector/No.: D. Palumbo, 1994-60 Date: August 24, 1994
Locality: `Ōla`a Forest Pu`u Unit at fenceline between Transects 4 and 5

*Collector/No.: G. E. Olson, 1101 Date: February 6, 1939
Locality: Kulani Trail, 1.5 mile

*Collector/No.: T. Herat, R. Herat, & P. Higashino, 584
Date: June 15, 1974
Locality: `Ōla`a Forest Reserve, ca. 10.8 km from junction of Stainback Highway and Highway 17, toward Kulani Prison

Cyanea pilosa subsp. *pilosa?* A. Gray
Collector/No.: L. W. Cuddihy, 2120 Date: July 17, 1987
Locality: `Ōla`a Tract, elevation ca. 4,300 ft.

Cyanea tritomantha A. Gray
Collector/No.: L. L. Abbott, 96-001 Date: June 21, 1996
Locality: `Ōla`a Forest, Koa Unit, transect 14 at 380 m.

*Collector/No..: T. Herat, R. Herat, and P. Higashino, 583
Date: June 15, 1974
Locality: `Ola`a Forest Reserve, ca. 10.8 km from junction of Stainback Hwy and Hwy 17, toward Kulani Prison, at ca. 1070 m

Cyrtandra giffardii Rock
Collector/No.: L. W. Cuddihy, 2343 Date: June 28, 1990
Locality: `Ōla`a Forest, Transect 16

Collector/No.: L. W. Pratt, 2633 Date: May 11, 1993
Locality: `Ōla`a Forest, Koa Unit, Transect 14

Collector/No.: L. W. Pratt, 2742 Date: January 14, 1994
Locality: `Ōla`a Forest, Koa Unit, Transect 18

Embelia pacifica Hillebr.
Collector/No.: L. W. Pratt and D. K. Palumbo, 2811
Date: July 20, 1994
Locality: `Ōla`a Forest, Ag Unit, along lower fenceline

APPENDIX 1 (Continued)

Eurya sandwicensis A. Gray

Collector/No.: Otto Degener and Isa Degener, 31,552
Date: January 19, 1967
Locality: Southwest corner near Wright Road, HAVO Wilderness Area.
Notes: Handwritten note says: "We did find a *Eurya* tree along fence line, on pasture side. The tree had miraculously escaped a bulldozer that had dumped plant wreckage about it."

*Collector/No.: G. O. Fagerlund and A. L. Mitchell by Mr. Horner, 169
Date: November 18, 1942
Locality: Keake[a]lani School, 29 mile

*Collector/No.: L. W. Cuddihy, 2302 Date: December 16, 1989
Locality: Pu`u Maka`ala NAR, Disappointment Road

Joinvillea ascendens Gaud. Ex. Brongn. & Gris. subsp. *ascendens,* None in HAVO Herbarium

Labordia hedyosmifolia Baill.

Collector/No.: Marie Morin, sn Date: November 1991
Locality: `Ōla`a Large Tract, outside Pu`u Unit, Transect 3C

Collector/No.: L. W. Cuddihy, 2303 Date: December 16, 1989
Locality: `Ōla`a Tract on trail from end of Disappointment Road in Pu`u Maka`ala NAR

*Collector/No.: T. Herat, R. Herat, & P. Higashino, 925
Date: July 6, 1974
Locality: `Ōla`a Forest Reserve, ca. 9.6 km from the junction of Stainback Hwy and Hwy 17, toward Kulani Prison, at ca. 870 m.

Labordia hirtella H. Mann

Collector/No.: L. W. Pratt, 2525 Date: Oct. 28, 1992
Locality: `Ōla`a Pu`u Unit, Transect 5B, 516 m

Collector/No.: L. W. Cuddihy, 1983 Date: October 4, 1985
Locality: `Ōla`a Small Tract

Collector/No.: L. W. Cuddihy, 1920 Date: May 31, 1985
Locality: `Ōla`a Large Tract, Pu`u Unit, Transect 1

APPENDIX 1 (Continued)

Liparis hawaiensis H. Mann, None in HAVO Herbarium from `Ōla`a Forest

Marattia douglasii (Presl) Baker
*Collector/No.: R. L. Fowler, 201 Date: July 10, 1937
Locality: 29 mile Road, collected outside of Park

Collector/No.: L. W. Pratt and D. K. Palumbo, 2802
Date: July 13, 1994
Locality: `Ōla`a Ag Unit, Transect 10

*Nothocestrum longifolium*A. Gray
*Collector/No.: T. Herat, R. Herat, & P Higashino, 590
Date: June 15, 1974
Locality: `Ōla`a Forest Reserve, ca. 10.8 km from junction of Stainback Highway and Highway 17, toward Kulani Prison

Collector/No.: P. K. Higashino and A. Kikuta, 10,332
Date: May 16, 1984
Locality: Large Section of `Ōla`a Tract, elevation 3,900 ft.

Collector/No.: L. W. Cuddihy and Tim Tunison, 1955
Date: Sept. 9, 1985
Locality: `Ōla`a Small Tract

Collector/No.: L. Whiteaker, sn Date: Jan. 6, 1986
Locality: `Ōla`a Tract behind U. H. Agriculture Station

Collector/No.: Larry Katahira and Dan Taylor, sn
Date: Feb. 24, 1987
Locality: `Ōla`a Forest, Large Tract, 800 m from Maruyama Farm

Collector/No.: David Palumbo, 94-031 Date: May 25, 1994
Locality: `Ōla`a Forest, Pu`u Unit, transect 5C, elevation ca. 4,000 ft.

Collector/No.: David Foote, sn Date: Aug. 26, 1993
Locality: `Ōla`a Forest

Phyllostegia ambigua (A. Gray) Hillebr.
Collector/No.: L. W. Cuddihy and S. J. Anderson, 1869
Date: April 3, 1985
Locality: Small Tract `Ōla`a on fenceline

APPENDIX 1 (Continued)

Phyllostegia floribunda Benth.
Collector/No.: Don Drake, 95 Date: July 7, 1991
Locality: `Ōla`a Tract [fenceline on interior of Ag Unit]

Phyllostegia vestita Benth. Date: March 5, 1992
Collector/No.: L. W. Cuddihy, 2468 Date: March 5, 1992
Locality: `Ōla`a Tract, Puna District, elevation ca. 4,200 ft.

Collector/No. D. Palumbo, 1994-57 Date: May 26, 1994
Locality: `Ōla`a Forest, Pu`u Unit, Transect 5C

Collector/No.: Karl Magnacca, sn Date: June 29, 1995
Locality: `Ōla`a Forest, Puna District, elevation ca. 4,000 ft, outside pig exclosure on Transect 5C

Phytolacca sandwicensis Endl.
Collector/No.: L. W. Cuddihy and Mike Gates, 1990
Date: Oct. 15, 1985
Locality: `Ōla`a Small Tract

Pisonia brunoniana Endl.
Collector/No.: L. W. Pratt, 2942 Date: June 4, 1996
Locality: `Ōla`a Forest, Small Tract, inside fence from Pole 44 on Wright Road

Platydesma spathulata (A. Gray) B.Stone
Collector/No.: C. Forbes, sn Date: Sept 23, 1998
Locality: `Ola`a Puu Unit

Pritchardia beccariana Rock, None in HAVO Herbarium from `Ōla`a Forest

Rumex giganteus W. T. Aiton
Collector/No.: L. W. Cuddihy, 1885 Date: April 25, 1985
Locality: `Ōla`a Small Tract

Collector/No.: L. W. Pratt, 2943 Date: June 5, 1996
Locality: `Ōla`a Forest, Koa Unit, Transect 18, elevation ca. 3,800 ft (plot 2)

Schiedea diffusa A. Gray
Collector/No.: D. K. Palumbo, sn Date: May 1996
Locality: Seed from `Ōla`a Forest, Ag Unit
Notes: Vine cultivated in Park greenhouse from seed collected in July 1995

APPENDIX 1 (Continued)

Sicyos alba (St. John) Telford
Collector/No.: Tim Tunison, sn Date: June 7, 1989
Locality: `Ōla`a Forest, Koa Unit, Transect 17
Notes: Sterile, Identification uncertain

Collector/No.: L. W. Pratt and L. L. Abbott, 2950 Date: June 28, 1996
Locality: `Ōla`a Forest, Koa Unit, Transect 17, 720 m

Stenogyne macrantha Benth.
Collector/No.: Andrew Kikuta, sn Date: May 16, 1991
Locality: `Ōla`a tract, Transect 12

*Stenogyne scrophularioides*Benth.
Collector/No.: L. W. Cuddihy, 2469 Date: March 5, 1992
Locality: `Ōla`a Tract, Transect 5C, elevation ca. 4,200 ft

Collector/No.: D. Palumbo, 1994-15 Date: January 14, 1994
Locality: `Ōla`a Forest, Koa Unit, Transect 16

Tetraplasandra oahuensis (A. Gray) Harms
Collector/No.: Thomas R. Belfield 133,134 Date: April 9, 1998
Locality: `Ola`a Pu`u Unit, transect 5B, elevation ca. 4,100 ft.

Touchardia latifolia Gaud.
Collector/No.: L. W. Cuddihy, 1982 Date: Oct. 4, 1985
Locality: `Ōla`a Small Tract

Collector/No.: L. W. Cuddihy and Tim Tunison, 1956
Date: Sept. 9, 1985
Locality:`Ōla`a Small Tract

Collector/No.: Larry Katahira, sn Date: June 30, 1987
Locality: `Ōla`a Large Tract

Trematolobelia grandifolia (Rock) Degener
Collector/No.: L. W. Cuddihy and N. G. Zimmer, sn
Date: Oct. 15, 1989
Locality: `Ōla`a Small Tract

Collector/No.: Michelle Fulton, 501 Date: Dec. 15, 1991
Locality: `Ōla`a Large Tract, Transect 3C, 4,100 ft elevation

APPENDIX 1 (Continued)

Trematolobelia grandifolia (Rock) Degener (Continued)

Collector/No.: David Foote, sn Date: Nov. 11, 1993
Locality: `Ōla`a Large Tract, Transect 3C, 4,100 ft elevation
Notes: Fruit green; branch found on trail, cut by machete

Collector/No.: D. R. Drake and L. Cuddihy, 68
Date: Feb. 10, 1991
Locality: `Ōla`a Large Tract

Urera glabra (Hook. & Arnott) Wedd.

Collector/No.: L. W. Cuddihy and Tim Tunison, 1984
Date: Oct. 4, 1985
Locality: `Ōla`a Small Tract

Collector/No.: Tim Tunison, sn Date: April 18, 1994
Locality: `Ōla`a Large Tract, between Transects 16 and 17